ELECTRICAL APPLIANCES

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OF THE

PRESENT DAY;

BEING A REPORT ON THE

PARIS ELECTRICAL EXHIBITION OF 1881.

BY

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Corps of Engineers, U. S. A.,

HONORARY COMMISSIONER TO THE EXHIBITION, AND MILITARY DELEGATE
TO THE CONGRESS OF ELECTRICIANS.

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INTRODUCTION.

THE writer of this report was directed by the Hon. Secretary of War to visit Paris in the summer of 1881, and to collect such information in regard to the Paris Electrical Exhibition as would be of interest or value.

As a consequence of his selection for this duty the Hon. Secretary of State appointed him Honorary Commissioner from the United States to the Exhibition, and Military Delegate to the Congress of Electricians. He was also appointed, while at the Exhibition, a member of the jury to determine the awards, and in addition had immediate charge of the exhibit of the Signal Service of the U. S. Army.

This multiplicity of duties, while giving him more facilities for examination than were possessed by the ordinary visitor, was rather embarrassing, as it entailed continual draughts on his time.

This was the first international exhibition devoted exclusively to electricity, and was complete in most details, covering thoroughly the whole ground, with the exception of the application of electricity to torpedoes, in which class there were but few exhibits, and these were so hedged around with secrecy that but little information could be obtained concerning them.

As was to be supposed, the Palais de l'Industrie, in which the Exhibition was held, was peculiarly well lighted, and the Exhibition was specially noted for the number and variety of machines for generating electricity and for the appliances used in electric lighting. Thus two subjects are therefore treated in considerable detail.

In some cases a slight history of antecedent inventions is prefixed to the description of objects exhibited, to show more clearly the progress and improvement made.

The chapter on the application of the Electric Light to Light-houses has already been published in *Science*.

In Mr. Kaiser's report on his torpedo-alarm his own words and expressions have been retained ; the slight idiom of his language does not make his meaning the less clear.

In preparing the report liberal use has been made of descriptions furnished by exhibitors and inventors, and published in current periodicals, especially *Engineering*, *The Electrician*, and *The Telegraph Journal*, published in London ; and *La Lumière Électrique* and *L'Électricien*, published in Paris.

D. P. H.

WASHINGTON, *July 17, 1883.*

SIR: I have the honor to report that on March 13, 1881, I received the following:

WAR DEPARTMENT,
Washington City, March 8, 1881.

Orders:

That for the purpose of acquiring information respecting late inventions and improvements in electricity, Capt. D. P. Heap, Corps of Engineers, will proceed to Paris, France, via Liverpool and London, England, on or about the 15th July, 1881, and will be present at the International Exhibition of Electricity, to be held at Paris from the 1st August, 1881, to the 15th November following.

At the close of the Exhibition Captain Heap will return to the United States via London and Liverpool.

On his return to the United States Captain Heap will make a detailed report of the information acquired by him to the Chief of Engineers, for the use of the War Department.

ALEX. RAMSEY,
Secretary of War.

These orders were indorsed as follows:

OFFICE OF CHIEF OF ENGINEERS, U. S. ARMY,
March 11, 1881.

Respectfully forwarded to Capt. D. P. Heap, Corps of Engineers, Buffalo, N. Y.
By command of Brig. Gen. Wright.

GEORGE H. ELLIOTT,
Major of Engineers.

As a consequence of my selection by the War Department for this duty, the State Department appointed me honorary commissioner from the United States to the Paris Exposition, and military delegate to the Congress of Electricians.

The Chief Signal Officer, desiring to make an exhibit of signal apparatus at the Exposition, I was requested to take charge of it, and consented with pleasure.

Sergt. A. Eccard, of the Signal Service, was directed to accompany the exhibit to Paris, and to attend to the details of unpacking and installing it.

I sailed for Paris on July 2, and arrived in time to have the Signal Service exhibit ready by the opening day, and, in connection with the other commissioners, aided in getting the United States section in presentable condition.

During the entire exhibition my duties as commissioner, though not specially arduous, kept me quite busy, and as in addition I was a member of the Congress of Electricians and also one of the jury to determine the awards, I found that there was comparatively little time which I could devote to the principal object of my journey, *i. e.*, collecting information useful to this Government of the improvements in electrical appliances.

On my return to America I was ordered to duties which engrossed

nearly all my time. In such spare moments as I could find I worked on my report, but it was not until last winter that I could devote much attention to it, and I now submit the result of my labors.

The Exposition covered the whole ground of electric science, and was complete in nearly every detail except in its application to torpedoes. The various nations possessing torpedo systems preferred to keep their methods secret, not believing that in case of war their patented inventions would be held sacred. Hence the information gathered in this field will be found to be but meager.

The Exposition was specially noted for the number and variety of machines for generating electricity and for the appliances for using electricity for lighting. These two subjects are therefore treated in considerable detail.

In preparing the report, in addition to personal examination, I made liberal use of descriptions of apparatus furnished by exhibitors and inventors, and published in current periodicals.

I am specially indebted to *Engineering*, *The Electrician*, and *The Telegraph Journal*, published in London, and to *La Lumière Electrique* and *L'Electricien*, published in Paris.

The greater part of the chapter on application of electric light to lighthouses was published by me in *Science* during March and April of this year.

I have not always confined myself to the objects exhibited, but in some cases have given a slight history of antecedent inventions, in order to show their progress and improvement.

Those who desire fuller information on the subject of electric lighting are referred to "Electric Illumination," by James Dredge, mainly compiled from *Engineering*. This work was published while I was at work at my report, and descriptions in both will be found in many cases to be very similar, as both were derived from the same sources. "Electric Illumination" is moreover a nearly complete history of the subject, and is naturally more full than a report of an exhibition would be.

I have selected those subjects which seemed to me would be of the most use to the War Department. Information was, however, collected on many other subjects belonging to other branches of electrical science, on which an additional report will be submitted if desired.

In Mr. Kaiser's report on his torpedo alarm I have thought it best to retain his own words and expressions; the slight quaintness of his language does not make it the less intelligible.

Very respectfully, your obedient servant,

D. P. HEAP,
Major of Engineers.

Brig. Gen. H. G. WRIGHT,

Chief of Engineers, U. S. A., Washington, D. C.

LIST OF ILLUSTRATIONS.

BATTERIES.

	Page.
FIG. 1.—The Tronvé battery, modified form	14
2.—The Tronvé sealed battery	14
3.—The Tronvé dry battery	15
4.—The Griscom bichromate battery	16
5.—The Siemens & Halské constant battery	17
6.—The Siemens & Halské form of Daniell's battery	18
7.—Siemens & Co.'s form of Marie Davy's battery	18
8.—Austrian form of Daniell's cell	19
9.—Bliss & Hill's gravity battery	19
10.—Battery of Dr. Moser	20
11.—Battery of M. GaiFFE	20
12.—Leclanché battery	22
13.—Battery of M. Maiche	23
14.—Howell's manganese battery	23
15.—Standard battery of the London post-office	25
16.—Skrivanow's bell-push battery	26
17.—Daniell's cell, modified by M. Planté	26

DYNAMO AND MAGNETO ELECTRIC MACHINES.

FIG. 18.—The Pacinotti ring with details, Figs. <i>a</i> , <i>b</i> , and <i>c</i>	29
19.—Plan of Pacinotti ring	30
20.—Perspective view of Pacinotti ring	31
21.—The Gramme armature	33
22.—The Gramme hand machine	33
23.—The Gramme five-light machine	34
24.—The Gramme machine for transport of force to a distance	36
25, 26.—The Gramme machine, self-exciting	37, 38
27, 28, 29, 30.—The Gramme electromotor	38
31.—Brush machine, section of ring	39
32.—Brush machine, arrangement of bobbins	40
33.—Brush machine	40
34.—Brush machine, completed armature	41
35.—Brush machine, commutator	41
36.—Brush machine, diagram showing connections	42
37, 38.—Siemens's dynamo	44
39.—Siemens's dynamo, diagram showing connections	45
40.—Siemens's dynamo, later form	45
41.—Siemens's dynamo, for refining metals	46
42.—Continuous current dynamo of Hefner Atteneck, diagram of bobbins	47
43.—Diagram showing theory of Hefner Atteneck's dynamo	48
44.—Details of Hefner Atteneck's dynamo	49
45.—Another form of Hefner Atteneck's dynamo	50
46.—Diagram of preceding	51

FIG. 47.—The Hopkinson Muirhead dynamo	52
48.—Section of Hopkinson Muirhead dynamo	53
49.—The Weston dynamo	55
50.—Armature and polar pieces of Weston dynamo	55
51.—Armature ring of Weston dynamo	55
52.—The Maxim dynamo	56
53.—The Guleher dynamo	57
54.—The Guleher dynamo, diagrams showing connections	58
55, 56.—The Edison dynamo, armature	60
57.—The Edison small dynamo	61
58.—The Edison dynamo, large size	62
59.—The Arago disk dynamo, first type	62
60.—The Arago disk dynamo, construction of bobbins	63
61.—The Arago disk dynamo, second type	64
62.—The Jurgensen dynamo	65
63.—The Jurgensen dynamo in section	66
64.—The Jurgensen dynamo, sketch showing interior magnet	67
65, 66.—The Jablochkoff alternating current dynamo, the inductor	68
67.—Shape of plate forming core of fixed coils of Jablochkoff dynamo	69
68, 69.—Section and end elevation of Jablochkoff dynamo	69
70.—Jablochkoff dynamo, perspective view of 32-light machine	70

ELECTRIC LIGHT FOR MILITARY PURPOSES.

FIG. 71.—Portable engine, boiler and dynamo	73
72.—Lenticular projector	77
73.—Lenticular projector, mounted on a cart	78
74.—Projectors for ships' boats	79
75.—Hand-power Gramme machine	80
76.—The Mangin projector	81
77.—The Mangin projector, side view	82
78.—Mangin projector for use with artillery	83
79.—Portable electric light apparatus for French military service	85
80.—Self-propelling engine, with dynamo	86

ELECTROMOTORS.

FIG. 81.—The Trouvé electromotor	91
82, 83, 84.—Details of Trouvé electromotor	92
85.—Boat propelled by Trouvé motor	92
86.—Rudder and propeller of boat	93
87.—The double induction motor	94
88.—Diagram showing theory of double induction motor	95
89.—Model of double induction motor	96
90.—Diagram showing connections, &c	96
91.—The Elias electromotor	98
92.—The Burgin spherical motor	99
93.—The Ladd Siemen's machine used as a motor	100
94.—Experimental form of the Deprez motor	101
95.—The Marcel Deprez motor	103
96.—Armature of Cloris Bandet motor	104
97, 98.—The Cloris Bandet motor	104
99.—Armature of Cloris Bandet motor	104
100.—The Cloris Bandet motor	104
101.—The Jablochkoff electromotor and details	104, 105, 106

EXPLODERS.

	Page
FIG. 102.—Siemens's magneto-electric mine exploder	107
103.—Siemens's dynamo-electric mine exploder.....	108
104.—Deprez's improved circuit breaker	111
105.—Deprez's magneto exploder (small model).....	112

LAMPS, ARC.

FIG. 106.—Cance's regulator	116
107, 108.—Cance's regulator, details.....	117
109.—Hedge's regulator	119
110.—Jaspar regulator, side view.....	121
111, 112.—Jaspar regulator, vertical sections	122
113, 114.—Jaspar regulator, horizontal sections	123
115, 116.—Jaspar regulator, details.....	123
117, 118.—Jaspar's system of the canalization of light.....	134
119.—Berjot's regulator.....	126
120.—Weston's regulator	127
121.—Weston's regulator, details	128
122.—Pilsen lamp, forms of cores	130
123.—Pilsen lamp, explanatory diagram.....	130
124.—Pilsen lamp, diagram showing construction.....	131
125.—Pilsen lamp, horizontal form.....	133
126.—Hedge's differential lamp	134
127.—Brush regulator	135
128, 129, 130.—Brush regulator, details of construction.....	136, 137, 138
131.—Brush regulator, diagram showing how one lamp can be cut out ...	139
132, 133.—Brush regulator, current governor	140, 141
134.—Gulcher regulator, side view.....	142
135.—Gulcher regulator, perspective	144
136, 137.—Gulcher regulator, diagrams showing several lamps in circuit.....	145, 146
138.—Siemens regulator, theory of construction.....	147
139.—Siemens regulator	148
140.—Gramme regulator.....	150
141, 142, 143.—De Mersanne regulator and details	151, 152
144.—De Mersanne's vertical lamp.....	153

LAMPS, INCANDESCENT.

FIG. 145.—Moleyn's lamp.....	156
146.—Edison lamp with platinum spirals.....	158
147.—King's lamp.....	160
148.—Kohn's lamp	162
149.—Bontguenne lamp.....	162
150.—Varley lamp.....	164
151.—Principle of the Reynier lamp	165
152.—Reynier lamp	166
153.—Werderman lamp.....	168
154.—Ducretet lamp	169
155.—Werderman lamp, Napoli system ; first arrangement.....	172
156.—Werderman lamp, Napoli system ; second arrangement.....	174
157, 158, 159.—Edison lamp with carbon loop	176
160, 161.—Edison lamp, process of making lamps and globes	178
162.—Edison bracket lamp	178
163, 164, 165.—Edison bracket lamp, details of joints and button	179
166.—Sections of conductors, Edison system	176
167, 168.—Junction boxes, Edison system.....	180, 181

	Page.
FIG. 169.—Switch, Edison system.....	182
170.—Current regulator, Edison system	183
171, 172.—Current meter, Edison system	184, 185
173.—Current meter, Edison system, showing connections.....	187
174.—Current meter, Edison system; details of zinc plates	187
175.—Automatic meter, Edison system	188
176.—Maxim lamp	189
177, 178.—Maxim current regulator and exciter.....	191, 192
179.—Swan lamp.....	193
180.—Hand lamp with Swan light	193
181.—Lane-Fox lamp.....	194
182.—Lane Fox regulator	195

LIGHT-HOUSES.

FIG. 183.—Map of coast of France, showing position of light-houses	202
184.—Commutator at La Hève	205
185.—Lantern at La Hève	206
186.—Interior of lantern at La Hève, showing rails and connections.....	207
187.—Summit of tower at Planier.....	208
188.—Details of optical apparatus at Planier	209
189.—Plan of building at Planier containing dynamos and engines	210
190.—Lantern at Planier	211
191, 192.—Arrangement of dynamo at Planier.....	212
193.—Commutator at Planier	213
194.—Commutator at Planier, perspective	214
195, 196.—English form of commutator	215, 216
197.—Serrin-Berjot lamp	217
198.—De Meritens machine	218
199.—De Meritens machine, transverse section	219
200.—De Meritens machine, longitudinal section	220
201, 202, 203.—De Meritens machine, details of armature bobbins.....	220
204, 205.—De Meritens machine, details of magnets.....	221
206, 207, 208.—De Meritens machine, details of collecting apparatus.....	221
209.—De Meritens machine, method of connecting armatures	221
210, 211, 212, 213.—Balestrieri reflecting apparatus, diagrams	224, 225, 226
214, 215.—Balestrieri reflectors, perspective.....	226, 227

MILITARY TELEGRAPHS.

FIG. 216.—Siemens alphabetical telegraph	228
217.—Siemens polarized alarm	229
218.—Siemens finger-key dial instrument.....	230

TORPEDO APPARATUS.

FIG. 219.—Sketch of harbor defended by torpedoes.....	233
220, 221.—Torpedo firing arcs	234
222.—Shutter signaling and firing instrument	235
223, 224.—Fixed and floating torpedoes.....	237
225.—Matthieson's circuit closer	238
226.—Buoyant torpedo, section	240
227.—Platinum fuse	240
228.—Matthieson's disconnecter.....	240
229.—Junction box.....	241
230.—Submarine battery	241
231.—McEvoy's system, key board	243

	Page.
FIG. 232.—McEvoy's system, junction box	244
233.—McEvoy's system, circuit closer and fuse	245
234.—McEvoy's system, diagram showing connections	245
235, 236, 237, 238, 239, 240.—Kaiser's torpedo alarm, showing details	247
241, 242.—Kaiser's torpedo alarm	248
243, 244.—Semispherical mine with Kaiser's torpedo alarm	249
245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258.—Kaiser's torpedo alarm, details of comparator and galvanometer	249

[The topics touched upon in this report are arranged under the following heads:]

	Page
BATTERIES	13
DYNAMO AND MAGNETOELECTRIC MACHINES	28
ELECTRIC LIGHT FOR MILITARY PURPOSES	71
ELECTROMOTORS	87
EXPLODERS'	107
LAMPS, ARC	114
LAMPS, INCANDESCENT	155
LIGHT-HOUSES	197
MILITARY TELEGRAPHS	228
TORPEDO APPARATUS	232

REPORT

ON THE

INTERNATIONAL EXHIBITION OF ELECTRICITY

HELD AT PARIS AUGUST 1-NOVEMBER 15, 1881.

BATTERIES.

LIST OF BATTERIES.

The Trouvé bichromate battery.	Battery of M. Gaiffé.
The Trouvé sealed battery.	Leclanché battery.
The Trouvé dry battery.	Battery of M. Maiche.
The Griscom bichromate battery.	Howell's manganese battery.
Siemens & Halske's constant battery.	Partz's bichromate battery.
Siemens & Halske's form of Daniell's battery.	Eldredge's litharge battery.
Siemens & Halske's form of Marie-Davy's battery.	Battery of Signor Piatti.
Austrian battery.	Standard battery of London post-office.
Bliss & Hill's battery.	Bell-push battery of M. Skrivanow.
Battery of Dr. Moser.	Battery of M. Desruelles.
	Daniel's cell, modified by M. Planté.

BATTERIES AND BATTERY MATERIAL.

THE TROUVÉ BICHROMATE BATTERY.

This is the battery devised by M. Trouvé for actuating the small motor invented by him.

This battery is a modification of the "*Pile bouteille*" devised by M. Grenet. Grenet's battery consists of a globular receiver in glass with a very wide neck; the electrôdes are composed of two pieces of retort carbon fixed to the cover of the battery, between which passes a zinc plate that may be placed in the liquid or withdrawn, so that there may be no de-

struction when the battery is not in use. The exciting liquid is water 100 parts, bichromate of potash 12 parts, sulphuric acid 25 parts.

M. Tronvé has modified this well known form, and has made it as shown in Fig. 1, which permits of its being easily cleaned, of the zines being rapidly amalgamated and replaced, and diminishes the resistance on account of the large surfaces obtained. The battery consists of two plates, N N, of hard rubber, which can easily be coupled with three other plates of the same material to form the vase; the plates support a rod, on which are placed the movable contacts carrying the carbons. The tube E is for blowing in air to assist in disengaging the bubbles of hydrogen, and to aid in the precipitation of a yellow powder that covers the carbons, and reduces the intensity of the current. Strips of rubber are placed above and below the carbons to prevent their contact with the zines.

FIG. 1.

FIG. 2.—The Trouvé sealed battery.

THE TROUVÉ SEALED BATTERY.

In this battery, which, though small enough to be carried in the vest pocket, is very powerful, the exciting liquid is a solution of bisulphate of mercury, and the electrodes are carbon and zinc; the vase is of hard rubber, in the upper part of which (see Fig. 2) is a tube of carbon, and inside the tube, but separated from it, a cylinder of zinc. When the battery is held

upright the liquid does not touch the zinc, and no action takes place. When it is desired to make the battery act, the vase is simply laid on its side or turned upside down.

The battery polarizes rapidly, and in closed circuit is soon exhausted; the bisulphate of mercury can readily be renewed, however. M. Trouvé uses this battery for his electric jewelry, which consist of small figures, insects, birds, butterflies, &c., used as scarf-pins or ornaments, and animated at the will of the wearer by electricity.

THE TROUVÉ DRY BATTERY.

This is composed of two disks (see Fig. 3), one of zinc, the other of copper, separated by a number of paper disks, slightly less in diameter, and moistened with a solution of sulphate of zinc and of sulphate of copper in the part nearest to the disks. These salts being hygrometric always keep the battery in a proper state of moisture, and there is no action until the circuit is closed. Care must be taken that the copper rod connecting with the copper disk, which is the lower one, be insulated from the paper disks to prevent local action, and that the whole arrangement be placed in a glass vase with a slate top to prevent its drying. Thus made the element can work for a year without needing attention.

It is evident that after a variable time, depending upon the amount of work which it is called upon to perform, the battery will be exhausted. All that is then necessary to do is to again moisten the lower part of the battery in a heated and saturated solution of sulphate of copper. As to the sulphate of zinc, it is constantly formed by the action of the apparatus, and it is never necessary to renew it.

This battery has the same electromotive force as a Daniell battery, from which it only differs in form. Its resistance varies with the diameter of the copper and zinc disks and with the thickness of the pile of paper disks. For a given diameter of the disks the quantity of the paper cannot be too much diminished without causing the battery to lose its durable qualities, which is one of its principal merits.

FIG. 3.—The Trouvé dry battery.

THE GRISCOM BICHRIMATE BATTERY.

The battery devised by Mr. Griscom for use with his electromotors is also a modification of the "Grenet" battery.

It is so arranged (see Fig. 4) that the plates can be lifted clear of the liquid by a spring and allowed to drain. This avoids the expense of having the battery recharged frequently, and as it does not waste when not at work it will last a long time with a single charge.

FIG. 4.—The Griscom bichromate battery.

The amount of current is regulated by dipping the plates more or less in the liquid by means of the pedal shown at the side of the box. This motion of the plates also tends to free them from hydrogen bubbles and to prevent the battery from polarizing.

SIEMENS & HALSKE'S CONSTANT BATTERY.

This battery is a form of the Daniell's cell (see Fig. 5), and was introduced some years ago. It contains a diaphragm of paper pulp strongly saturated with salt to prevent the mixture of the solutions and the unnecessary consumption of zinc and sulphate of copper.

A is a glass jar, at the bottom of which is placed a cross of sheet copper, K, attached to a copper wire, $f+$, and over this a tube, C, of unglazed porcelain, the lower part of which is widened out bell-fashion. Between the porous bell and the glass vessel the paper pulp is put to the height e and pressed firmly down. This forms the diaphragm, and is covered on top

FIG. 5—Simens & Halske's constant battery.

with a piece of blotting paper or flannel, on which the zinc Z rests. Crystals of sulphate of copper are placed in the porcelain tube and acidulated water in the jar A, so as to cover the zinc.

SIEMENS & HALSKI'S FORM OF DANIELL'S BATTERY.

This consists of a zinc cylinder, Z, immersed in acidulated water, and a copper cylinder, C, in a solution of sulphate of copper, the liquids being separated by a porous diaphragm, P. (See Fig. 6.)

FIG. 6.—Siemens & Halske's form of Daniell's battery.

MARIE DAVY'S BATTERY.

FIG. 7.—Siemens & Co.'s form of Marie Davy's battery.

SIEMENS & CO.'S FORM OF MARIE DAVY'S BATTERY.

The form used by Siemens & Co. (see Fig. 7) consists of a zinc cylinder, Z, and a carbon plate, C. The exciting liquid is a solution of proto-sulphate of mercury. This battery is sometimes used on account of its high electro-motive force and the comparatively small space the cells occupy.

AUSTRIAN BATTERY.

The following form of the Daniell cell (see Fig. 8) was shown in the Austrian section, and is the device of Herr Kohlfürst.

It consists of a glass jar, A, with a contraction, *bb*, at its lowest part. This jar is covered with a cast-iron lid, D, to prevent evaporation, and a conical plate of pig zinc, Z, is connected to it by a brass pin, *c*, which is screwed into the lid, and carries at its upper end a terminal, *x*. The zinc forms one pole of the battery; the other is an S-shaped piece of lead lying on the bottom of the cell. An insulated wire, *f*, runs from this plate outside the cell through a hole in the cover, and forms the other terminal. The bottom of the jar, from the lead plate to the narrow neck, *bb*, is filled with crystals of sulphate of copper, and over the neck is laid a plate of unglazed earthenware, *t*. The exciting liquid is a solution of sulphate of magnesia, which is poured into the opening *l* in the cover. This is ordinarily kept closed by a cork. The E. M. F. of this element is about a volt; its I. R. about 5 Siemens units. It is said to be very constant and to require little attendance, and will last from six months to a year when once set up. It is used on the Buschtehrad Railway at Prague.

FIG. 8.—Austrian form of Daniell cell.

FIG. 9.—Bliss & Hill's gravity battery.

Another form of Daniell battery, designed by Messrs. Bliss & Hill and constructed by the Western Manufacturing Company of Chicago and New York, has a reservoir for the sulphate of copper at the bottom. (See Fig. 9.) The copper plate forms the separator between the solution of sulphate of copper and sulphate of zinc. battery.

It is a simple form of gravity

BLISS & HILL'S BATTERY.

BATTERY OF DR. MOSER.

A simple plan of keeping the two solutions from mixing in a Daniell cell was exhibited by Dr. James Moser, of the Société Générale des Téléphones, Paris. This plan is shown in figure 10. A is a long glass jar fitted with a lid of cork, B. Through the cork a rod of zinc, E, is inserted to form the positive plate, and a disk of copper, D, at the bottom of the jar is the negative plate; an insulated wire runs from this plate through the cover. The whole cell is filled with a solution of sulphate of zinc, and crystals of sulphate of copper are dropped upon the copper plate, where they dissolve. The solution of sulphate of copper is prevented from rising into the upper half of the jar by means of the additional piece of zinc Z suspended in the liquid. Any sulphate of copper diffusing up as far as this plate is decomposed by the zinc, and metallic copper is deposited upon it. There is thus a definite line of demarkation between the two solutions at C. This cell is said to answer well as a standard.

BATTERY OF M. GAIFFE.

FIG. 10.—Battery of Dr. Moser.

FIG. 11.—Battery of M. Gaiffe.

When the circuit of a Daniell cell is open there is always a slight waste, owing to the reaction of the zinc upon the sulphate of copper. M. Gaiffe

has designed a form of battery to suppress this and at the same time to render the action more constant. (See Fig. 11.)

The apparatus is composed, 1st, of a glass jar, B, at the upper part of which is suspended a zinc cylinder, Z; 2d, a central vase, P, the upper part P O being porous, and the lower part J S being of ordinary glass; 3d, a cylinder of copper, C, contained in the central vase. This copper cylinder is prolonged into the rod C' C'', bent back into the jar B, outside the porous vase and curved horizontally into a ring, C'', around the central vase.

This cell is charged with a concentrated solution of sulphate of zinc or sulphate of magnesia, and crystals of sulphate of copper are placed at S, around the base of the central vase. In dissolving, these crystals first saturate the liquid contained in the part J S of the central vase, and when the solution arrives above the line J it permeates the porous vase and falls by its density to the bottom of the jar outside the sphere of action of the zinc. But this permeation of sulphate of copper operates slowly, and the circuit may be left open for weeks before any deposit of copper can be perceived upon the zinc. When the circuit is closed this cell, presenting less internal resistance between Z and C'' than between Z and C reduces first the sulphate of copper which has fallen to the bottom of the jar, the liquid in which soon regains its original purity, after which the action continues as in an ordinary Daniell cell.

The incrustation of the porous vase with copper is avoided by preventing any contact between the vase and the copper element.

LECLANCHÉ BATTERY.

The well-known Leclanché battery (see Fig. 12) was exhibited by various manufacturers. The following advantages are claimed for the new form with agglomerated plates:

Absolute constancy of resistance, whatever may be the electro-chemical work effected by the element;

The disengagement of electricity is immediate as soon as the battery is mounted and the circuit closed;

The battery will last longer than any other, on account of the depolarizing power of the manganese, which is utilized to the last atom;

The E. L. M. is considerable, in practice 15 Daniell elements can be replaced by 10 Leclanché;

It requires hardly any attention;

It can readily be renewed; when it is exhausted it is only necessary to change the depolarizing plates; this makes the battery very economical;

The weight and size are much diminished, and as the porous vase is no longer used there is less danger of breakage.

An essential condition for the good working of all Leclanché batteries

is that the sal ammoniac be free from all impurities, especially lead, which will be deposited in a metallic state upon the zinc, rapidly consuming the latter by local action.

FIG. 12.—Leclanché battery.

BATTERY OF M. MAICHE.

A modified form of Leclanché battery (see Fig. 13) was exhibited in the French section by M. Maiche. It consists of a glass vessel, A, containing in its upper part a porous vase, B, perforated with holes, which is attached to the ebonite cover. This vase is filled with fragments of gas carbon on which platinum has been deposited. From one of the terminals a platinum wire leads into the carbon and makes contact with the latter. An ebonite stem passes through the vase and supports a circular shelf, c, on which are laid two small cylinders of zinc surrounded with mercury; a platinum wire, d, descends from the other terminal and makes contact with the mercury. The external vessel is filled with a saturated solution of sal ammoniac, or water with a tenth of its weight of sulphuric acid, or bisulphate of soda.

The level of the water must not rise much above the level of the lower row of holes in the porous vase. The object of this is to make the greater part of the carbon humid by capillary attraction only, whilst the zinc is entirely immersed, and can therefore become entirely dissolved.

The advantages claimed are that the battery will last a long time with-

out recharging, and that it has high E. M. F. and low I. R., and consequently is well adapted for telegraphy or for ringing electric bells.

From the construction it seems as if small particles of platinized carbon might fall into the mercury and set up local action; this defect, if it exists, could no doubt be readily rectified.

FIG. 13.—Battery of M. Maiche.

FIG. 14.—Howells' Manganese battery.

HOWELLS' MANGANESE BATTERY.

Another form of Leclanché battery, devised by Mr. Howells and shown in the British section (see Fig. 14), avoids this defect by using a double diaphragm, one porous the other slotted. It consists of a stoneware outer jar, A A, inside of which is fixed the stoneware cell B B, called the “separator,” having a number of narrow slots cut in its wall; within the “separator” is placed an ordinary porous pot, C C, which contains a zinc rod, P, kept amalgamated by a little free mercury in the bottom of the cell.

In the space A' A', between the outer jar and the “separator,” is placed a rod of carbon, N, fitted with a brass terminal, and surrounding this rod is packed a mixture of graphite and dioxide of manganese in small pieces, together with some manganese sulphate or white manganese of commerce. The whole is sealed with a compound of bitumen, and a small hole is left for the escape of gases.

The battery is charged with a mixture of one part of sulphuric acid and four parts of water, which is poured into the middle compartment B' B', formed by the “separator” and porous cell; the latter is filled with

a solution composed of 25 grammes of ammonic sulphate dissolved in one litre of water.

The E. M. F. is about 2.14 volts or 12 per cent. higher than that of an ordinary Leclanché, and its I. R. is from 5 to 6 ohms. This comparatively low internal resistance is attributed to the presence of white manganese, which is a better conductor than the black. This battery can be readily cleaned.

PARTZ BICHROMATE BATTERY.

This battery was exhibited in the American section. Its chief peculiarity was in the form of the carbon plate, which is in the shape of a hollow cylinder with vertical slots cut out of it from near the top to the bottom; it incloses the ordinary zinc rod. The exciting liquid is a neutral solution of bichromate of potash. The E. M. F. is said to be 1.65 volts, I. R. only 1.6 ohms. The result is a powerful current from a single cell, and it is therefore well adapted for domestic purposes.

ELDRIDGE LITHARGE BATTERY.

This more novel form was also shown in the American section by Mr. J. Morgan Eldredge; it is of the ordinary shape and the plates are zinc and lead. The zinc cylinder is cast with lugs and is hung from the mouth of the jar. A square plate of lead is placed in the bottom and on it is strewed powdered litharge. The exciting liquid is a solution of chloride of ammonia. In the chemical action of the cell oxide of lead, chloride of ammonia and zinc are transformed into lead, water, chloride of zinc, and ammonia. No tests of the battery were given.

BATTERY OF SIGNOR PIATTI.

This battery, exhibited in the Italian section, is based on the observation made by its inventor, that when powdered coke is pressed into a hard mass and inserted between the two plates of a voltaic element, the carbon, though almost metallically conductive within certain limits of pressure, does not "short circuit" the cells, but, on the contrary, only serves to render the exciting liquid more conductive and powerful. It is claimed that an element thus constructed lasts longer without polarizing than one in which the coke is absent. The cell exhibited consists of the ordinary glass vessel containing the zinc cylinder, and within the cylinder is placed the ordinary porous pot. But the latter instead of containing the positive plate is packed with ground coke. The positive plate of silvered copper, or better, of silver, is simply laid upon top of the coke, and by means of a thumb-screw bearing upon its upper surface a pressure is applied to the coke paste so as to regulate its resistance and the activity of the cell. The exciting liquid is a solution of common salt, and it is necessary that the

coke should be neither too fine nor too coarse. It is first sifted in a sieve having meshes of 1 millimeter in diameter and afterwards cleaned from dust in a hair sieve. It is then filled into the porous pot and each layer is firmly pressed. The solution is poured into the outer vessel until it attains a level of 5 or 6 centimeters below the top of the coke, and more is added until the level of the liquid is no longer lowered by the absorption of the pot and its contents. When the circuit is closed the maximum current is obtained in about an hour.

In the action of the battery the common salt resolves itself into hydrate of soda, which passes to the carbon, while chloride of zinc remains in the liquid and hydrogen escapes from the pores of the carbon.

A short time after the battery is put in action the hydrate of soda traverses the porous diaphragm by osmose and encountering the chloride of zinc reproduces the decomposed chloride of sodium, and the hydrated oxide of zinc is deposited on the exterior surface of the diaphragm, from which it is easily removed by a spatula, in order to prevent an increase of internal resistance.

STANDARD BATTERY OF THE LONDON POST-OFFICE.

FIG. 15.—Standard battery of the London post-office.

This battery is designed to make very exact measurements; of which the error will not exceed .01 volt. It consists of a jar with two compartments (See Fig. 15); the one on the right contains a porous pot, in which are placed crystals of sulphate of copper and a copper rod; when the battery is not in use it is arranged as shown in the figure. The left-hand compartment is filled to a certain height with a half saturated solution of sulphate of zinc, and in it is the plate of zinc, Z; a cylinder of zinc, b, is placed in the bottom of this compartment, immediately below the plate of zinc Z; when it is desired to use the battery the porous vase is placed in the left-hand compartment, the level of the zinc solution rises and wets the zinc plate. The battery is then ready to work. When the measurements are finished the porous pot is replaced in the right-hand compartment. During repose all

the solution of sulphate of copper which had been mixed with the sulphate of zinc is deposited upon the cylinder *b*. The solution thus remains very clear. The E. M. F. of this element is 1.07 volts. The London post-office uses it for all trials of lines and apparatus.

THE BELL-PUSH BATTERY OF M. SKRIVANOW.

Among the minor novelties of the exhibition was this little battery (see Fig. 16), exhibited in the Russian section; it is contained in the ordinary bell-push. The sketch shows its construction. At the bottom of the bell-push is a plate of carbon, *C*, on which rests a ring of paraffine, *P P*, to contain a paste of chloride of zinc, *ch*. On this are placed a few disks of blotting paper, *B*, moistened with ammoniacal salts of mercury. A spring, *S*, supports a disk of zinc, *Z*, which can be pressed against the blotting paper by the push *E*. The terminals *T T* are in contact with the zinc and carbon, and when the push *E* is pressed down the battery is set in action; until then there is no action. It will ring a bell for twelve hours continuously, and when exhausted can readily be renewed, as the cover *A* can be unscrewed to obtain access to the interior.

BATTERY OF M. DESMELLES.

This is similar in principle to the above, but is larger and sufficiently powerful to redden a platinum wire. Asbestos, moistened with bichromate of potash and sulphuric acid, is placed on the carbon; as asbestos will absorb a large quantity of the fluid, the resistance is not much increased; it is used in connection with a gas lighter or to light a kerosene lamp.

FIG. 16.—Skrivanow's bell-push battery.

FIG. 17.

DANIELL CELL, MODIFIED BY M. PLANTÉ.

As M. Planté required a constant battery of large quantity to charge his accumulators or storage batteries he has made the following modifi-

cation of the Daniell cell. It consists of a cylinder of zinc inclosed in a porous vase, outside of which is a cylinder of copper. (See Fig. 17.) Between the copper cylinder and the containing jar is an annular space, 2 centimeters wide, filled with crystals of sulphate of copper; it can hold a charge of $1\frac{1}{2}$ kilograms. The figure shows the arrangement very clearly.

The advantages of this battery are the production of large quantities of electricity and absence of incrustation on the porous vase. It is evident that it should only be used on a closed circuit.

The following table may be useful as showing the electro-motive force of batteries most employed.

Name of battery.	Negative pole amalgamated zinc plunging in.	Positive pole.	Positive pole plunging in the following liquids.	Electro-motive force.
	<i>Parts.</i>			<i>Volts.</i>
Daniell, unity.....	{ Sulphuric acid .. 1 Water 4 }	Copper.....	{ Saturated solution of sulphate of copper. }	1. 079
Daniell, telegraph model.	{ Sulphuric acid... 1 Water .....12 }	Copper.....	{ Saturated solution of sulphate of copper. }	0. 978
Daniell	{ Sulphuric acid... 1 Water .....12 }	Copper.....	{ Saturated solution of nitrate of copper- }	1. 000
Marie Davy	{ Sulphuric acid... Water }	Carbon.....	{ Paste of protosulphate of mercury and water. }	1. 524
Leclanché	{ Water containing sal ammoniac in solution. }	Carbon surround- ed by peroxide of manganese and fragments of car- bon.	{ Solution of sal ammo- nica. }	1. 481
Bunsen	{ Sulphuric acid... 1 Water 12 }	Carbon.....	Fuming azotic acid.....	1 964
Bunsen	{ Sulphuric acid... 1 Water 12 }	Carbon.....	Ordinary azotic acid, 1.38	1. 888
Bichromate of pot- ash.	{ Sulphuric acid.. 1 Water .....12 }	Carbon.....	{ Bichromate of potash, } sulphuric acid. }	2. 028
Grove	{ Sulphuric acid... 1 Water 4 }	Platinum.....	Fuming azotic acid	1. 956

DYNAMO AND MAGNETO-ELECTRIC MACHINES.

LIST OF MACHINES.

The Pacinotti ring.	The Hopkinson-Muirhead dynamo.
The Gramme continuous-current machine.	The Weston dynamo.
The Gramme machine, for transport of power.	The Maxim dynamo.
The Gramme electromotor, small size.	The Gulcher dynamo.
The Brush machine.	The Schuckert dynamo.
The Siemens dynamo.	The Edison dynamo.
The Siemens dynamo, for refining metals.	The Arago disk dynamo.
The Hefner-Alteneck continuous-current dynamo.	The Jurgensen dynamo.
	The Jablochkoff alternating-current dynamo.

DYNAMO AND MAGNETO-ELECTRIC MACHINES.

A description of the various dynamo and magneto-electric machines cannot be better commenced than by giving details of a modest little model, in the Italian section, which was invented long before and contained within it the germ of the well-known machines of Gramme, Brush, de Meritens, and Edison, and is, in fact, the type of nearly all the direct-current electric machines of the present day. This model is now known as

THE PACINOTTI RING,

and was invented by Dr. Antonio Pacinotti, in the year 1860, and described by him in the "Nuovo Cimento," in 1864, under the title, "A Description of a Small Electro-Magnetic Machine," from which the accompanying diagrams were copied.

The author commences by describing a new form of electro-magnet, consisting of an iron ring, around which is wound a single helix of insulated copper wire completely covering the ring, and the two ends of the annular helix being soldered together an annular magnet is produced, enveloped in an insulated helix forming a closed circuit, the convolutions of which are in the same direction. If in such a system any two points of the coil situated at opposite ends of the same diameter of the ring be connected, respectively, with the two poles of a voltaic battery, the electric current, having two courses open to it, will divide into two portions, traversing the coil around each half of the ring from one point of contact to the other, and the direction of the current in each portion will be such as to magnetize the iron core so that its magnetic poles will be situated at the points where the current enters and leaves the helix, and a straight line joining these points may be considered as the magnetic axis of the system. It is clear that by varying the position of the points of contact of the

battery wires and the coil the position of the magnetic axis will be changed accordingly, and can be made to take up any diametrical position with respect to the ring, of which the two halves (separated by the diameter joining the two points of contact) may be regarded as made up of two semi-circular electro-magnets, having their opposite poles joined.

This is the first electro-magnet constructed the position of whose poles could be varied at will by means of a circular commutator.

By applying this principle Dr. Pacinotti constructed his machine. It

FIG. 18.

consists of an iron ring with sixteen teeth (Fig. *a*), forming between them sixteen spaces, which are filled up by coiling between them helices of insulated copper wire, *r, r, r, r* (Fig. *c*), and between them are placed wooden wedges, *m, m*, by which the helices are firmly held in their places; the coil is wound continuously in the same direction, each coil being formed of nine turns, and the terminating end of each coil is connected to the commencing end of the succeeding helix. The junctions so made pass through holes at regular intervals, made for this purpose in a wooden collar centered on the axis and attached at their lower extremities to the metallic contact pieces of the commutator shown at *c*, in Fig. *c*. Fig. 19 is a plan.

The commutator consists of a small box-wood cylinder, having circumferential slots in two rows of eight each, in which are fitted sixteen brass pieces slightly projecting from the surface of the wood, the position of

those in the upper row breaking joint with those in the lower. Each contact piece is in metallic connection with its corresponding conducting-wire, and, therefore, with the junction of two of the helices on the armature.

Against the edge of the commutator are pressed, by means of adjustable levers, two small contact rollers, $k\ k$, which are, respectively, connected with the poles of the battery (either through, or independently of, the coils of a fixed electro-magnet to be presently mentioned) so that, during the rotation of the ring the brass contact pieces of the commutator are brought successively into contact with the rollers; the magnetic axis of the ring will lie in the same plane as the line joining the points of contact of the battery and rotating helix, this axis remaining nearly fixed, notwithstanding the rotation of the iron ring in which the magnetism is induced.

FIG. 19.

In the apparatus shown in Figs. c and 19, the armature rotates between the two vertical limbs A B of a fixed electro-magnet, furnished with extended pole pieces, AA BB, Fig. 19, each of which embraces about six of the armature coils. The fixed electro-magnet is constructed of two vertical, cylindrical, iron bars, A and B, united at their lower extremities by a horizontal iron bar, FF, the one being rigidly and permanently attached to it, while the other is fastened to it by a screw, G, passing through a slot, so that the distance of the pole pieces from one another and from the armature-ring is capable of adjustment.

The connections of the machine shown in Fig. c are as follows : The positive current, entering by the binding post *h*, passes by a wire to the right-hand commutator-screw *l*, to the right-hand roller *k*, through the commutator to the ring, where it divides, each portion passing in an opposite direction, through the coils surrounding each half circumference of the ring, to meet again to form one current at the left-hand roller *k'*, whence the united current passes to *l'*, thence to the magnet coil A, to the magnet coil B, and, finally, to the binding post *h*, on the right-hand side of the figure, which is connected to the negative pole of the battery.

This method of coupling up is of great historical interest, for it is the

first instance on record of the magnet coils and armature of a machine being included in one circuit, giving to it the principle of construction of a dynamo-electric machine, and antedating in publication by two years the instruments of Siemens, Wheatstone, and Varley, and preceding them in construction by a still longer period.

In order to obtain the best effect from the electro-magnet, Pacinotti provided the two poles with soft iron extensions, as mentioned above. Strips of brass, EE, FF, Fig. 19, are attached to these pole pieces, to give them greater rigidity. In the elevation, Fig. e, the pole pieces are left out to show the ring more clearly, but they are shown in Figs. 19 and 20, the latter being a perspective view, taken from the instrument itself at the exhibition.

FIG. 20.

With this apparatus Dr. Pacinotti made several interesting experiments to determine the amount of mechanical work produced by the machine when worked as an electro-magnetic engine and the corresponding consumption of the elements of the battery, the results being that, to effect one kilogrammeter of mechanical work 33 milligrams of zinc were consumed in the battery. In another experiment 36 milligrams per kilogrammeter were consumed.

He points out that, although these results do not show any special advantage in his machine over those of other construction, still they are very encouraging, when it is considered that the apparatus with which the experiments were made were full of defects of workmanship, the commutator being badly mounted on the axis, causing the contacts between it and the rollers to be very imperfect and unequal.

In his communication to the "*Nuovo Cimento*," Dr. Pacinotti gives the following reasons which led him to construct this apparatus :

1. The current never ceases to flow in the helices, and the machine is not set in motion by a series of more or less rapidly succeeding impulses, intermittent in their action, but by two constantly acting forces producing a more uniform effect.

2. The annular form of the revolving armature helps, with the foregoing method of successive action, to give regularity to its motion, and to reduce the loss of motive power by friction, &c.

3. No attempt is made to suddenly magnetize and demagnetize the iron core of the armature, as such changes of magnetization would be retarded by the setting up of extra currents, and also by the permanent residual magnetism which cannot be entirely eliminated from the iron; with this annular construction such changes are not required, all that is necessary being that each portion of the iron of the armature, continually under the influence of the electro-dynamic forces, should pass through the various degrees of magnetization in succession.

4. The polar extension pieces of the fixed magnet, by embracing a sufficiently large number of the teeth of the iron ring continue to exercise an influence upon them almost up to the point at which their magnetization ceases when passing the neutral axis.

5. The sparks, while being increased in number, are diminished in intensity, there being no strong extra currents produced at the breaking of the circuit. When the machine is in rotation a continuous current is induced in the circuit in opposition to that of the battery.

And this leads to what is by far the most interesting part of Dr. Pacinotti's paper, published as it was more than nineteen years ago.

In the part referred to Dr. Pacinotti states that it occurred to him that the value of the apparatus would be greatly increased if it could be altered from an electro-magnetic to a magneto-electric machine, so as to produce a continuous current. Thus, if the electro-magnet A B (Figs. c and 19) be replaced by a permanent magnet, and the armature be made to revolve, the apparatus would become a magneto-electric generator, which would produce a continuous induced current, always in the same direction; and, in analyzing the action of such a machine, he observes that, as the position of the magnetic field is fixed and the iron armature with its coils rotates within it, the action may be regarded as the same as if the iron ring were made up of two fixed, semicircular, horseshoe magnets, with their similar poles joined, and the coils were loose upon it and were caused to rotate over it.

Dr. Pacinotti explains the physical phenomena involved in the induction of the electric currents in the armature when the machine is in motion, calls attention to the fact that the reversal of the direction of rotation reverses the direction of the current generated, goes on to show the obvious advantages in constructing electric generating machines upon this principle and points out the reversibility of the apparatus.

All these facts are familiar enough now, but it must be remembered that they are records of experiments made more than twenty years ago, and it is also a curious fact that so suggestive and remarkable a paper should have been published so far back as 1864 without producing sooner a revolution in electric science.

The jury of the International Exhibition of Electricity showed their appreciation of Dr. Pacinotti's discovery by awarding him a *diplome d'honneur*, one of their highest awards.

THE GRAMME CONTINUOUS CURRENT MACHINE.

As the principle of this machine is identical with that of the Pacinotti ring, it will not be necessary to describe it; it will be sufficient to give

FIG. 21.

some details of its construction, and to describe the various types made for special purposes.

The distinguishing feature of the machine is its armature, of which the

FIG. 22.

ring A (Fig 21) is generally made of soft iron wire to enable it to be magnetized and demagnetized rapidly. The figure shows the armature only partially complete. At the upper part BB are the helices of insulated copper

wire, connected to the radiating pieces $R R'$, also insulated from each other and bent at right angles, parallel to the axis, and extending beyond the armature to R' , thus forming the commutator, as shown in Fig. 22, in which will also be seen the collecting brushes, rubbing against the pieces $R R'$, in a plane at right angles to the line of the poles A and B .

This machine will furnish continuous currents, whose direction will change with that of the rotation ; the intensity of the current will increase

FIG. 23.

with the velocity of rotation, and the current will be in tension or quantity according as the armature is wound with thin or thick wire ; but, as the interior resistance increases as the dimension of the wire diminishes, better results are obtained in most cases by the use of thick wire. But it is easy to understand that if the exterior circuit has a very great resistance, as in telegraph lines, fine wire had better be used.

The machine exhibited for generating electricity for five arc lights, consists of two cast-iron standards, Fig. 23, in the center of which a bear-

ing is formed for the driving-shaft, on which the ring is mounted ; near the top and bottom of each frame a face is formed in which there is a transverse groove to receive the cores of the electro-magnets, which are flat, rectangular bars 11.93 inches long by 1.26 inches thick. These cores, besides resting in the grooves, are secured by bolts passing through the frame, three at each end. The wire wound on these cores brings them to the form shown in the figure. In the middle of each magnet is the pole-piece 4.72 inches thick, slightly wider than the diameter of the armature. Their inner faces are semi-circular, so as to almost embrace its complete circumference. The shaft carrying the armature is extended at one end beyond the frame, to take the driving-pulley, 7.87 inches in diameter ; the size of the shaft varies from 2.17 inches, in the center, to 1.13 inches at the end. The armature is carried on a wooden core, 5.94 inches wide, and of such diameter as to fit tightly within the armature, which is wound upon a core 4.76 inches wide. The outside diameter of the finished armature is 10.26 inches.

The armature is strengthened by the addition of two bands or hoops. The commutator or collector is mounted on the wooden core by means of a copper ring, fastened by screws to the core.

The brushes are controlled by an endless screw operated from outside the frame, so that their position may be regulated to secure the best effect.

The ordinary oiling of the bearings is effected by the two little glass reservoirs at the top of the frame. In addition, there are two boxes for grease formed in the casting of the frame, which are filled with tallow. This tallow will only melt in case the temperature of the shaft becomes too high.

The following are some of the measurements, &c., of this machine :

Total length, including pulley	inches..	32.09
Width	do....	19.69
Height	do....	21.19
Height of axis of shaft, above base.....	do....	11.02
Diameter of pulley	do....	7.87
Width of belt.....	do....	3.94
Total weight.....	pounds..	792
Resistance of armature.....	ohms..	1.5
Weight of wire on armature.....	pounds..	24.2
Resistance of electro-magnet	ohms..	3
Weight of wire on electro-magnet	pounds..	140
Outside diameter of armature.....	inches..	10.26
Width of armature.....	do....	5.90

This machine can feed from one to five lamps, by varying the speed at which it is driven and the resistance of its conductors.

The following table shows the most suitable speeds and resistances, the

space between the carbons during work, and the length of arc at point of extinction :

Number of lamps.	Number of revolutions per minute.	Resistance of conductor in ohms.	Normal distance apart of carbons in millimeters.	Length of arc at point of extinction in millimeters.
1.....	500	1.00	.25	.60
2.....	700	2.00	.25	.57
3.....	975	3.00	.25	.55
4.....	1,125	4.10	.25	.55
5.....	1,300	5.50	.25	.55

This machine has been specially devised to furnish electricity for Gramme arc lights. M. Gramme does not believe that arc lights of feeble intensity and with a steady light can be obtained. So, in place of trying to divide the current he prefers to construct machines of great power, feeding several intense lights in the same circuit.

FIG. 24.—Machine for the transport of force to a distance.

The new type of Gramme machine, for the transport of power to a distance, is shown in Fig. 24. The frame, in the shape of an eight-sided polygon, incloses and protects all the interior parts. The machine is very

compact, occupies but little space, and is not liable to damage in transportation. The electro-magnets are four in number, which naturally requires the use of four brushes for collecting the electricity.

A machine of this type will weigh about 1,150 pounds, and it is claimed will transport useful work, of from 6 to 8 horse-power, for a distance of over 3 miles.

The useful work given out by the receptive machine is about 50 per cent. of that required to drive the generator. In some of the smaller machines, under certain conditions, the useful work has been as high as 57 per cent. The electro-motive force of this machine exceeds 150 volts.

FIG. 25.

Another machine, shown in Figs. 25 and 26, has two revolving armatures alongside of each other, one for exciting the magnetic field, the other for generating the electricity. In the figure the two armatures cannot be seen, as they are hidden by the electro-magnets, which in this type are vertical and help to form the frame. In Fig. 25 both collectors are shown at DD and CC; the handle K serves to break the inducing current, or to regulate it by the introduction of proper resistances. The handle A is the interrupter of the principal circuit; the brushes are regulated, as to their position on the commutator, by the endless screws at EE.

The machine for galvano-plasty has an armature composed of copper bars, analogous to that of Siemens, which it somewhat resembles, only it has two collectors, one at each end, thus forming two distinct coils, which can be coupled in quantity or tension, as desired.

FIG. 26.

FIG. 27.—Longitudinal section.

FIG. 28.—End view.

FIG. 29.—Plan.

FIG. 30.—Cross-section.

The most recent type is that of the little motor, shown in Figs. 27, 28, 29, and 30. The armature is placed at the extremity of the electro-magnets; the latter are supported on one side by a circular plate, forming, at the same time, a connection for the magnets and a frame for the machine; at the other side their cores are produced, so as to inclose the armature and to envelop it in the magnetic field; they are then reunited to the frame.

This little motor is of very reduced size and of an attractive shape. The conditions seem to be good, the electro-magnets being entirely to one side of the plane perpendicular to that of the armature (Fig. 30) there will, in consequence, be no dead points. The cores of the magnets are of large size; but, as their cross-section is that of a crescent with rounded ends, it would seem as if it would be difficult to make the wires keep this shape on the concave side.

It will be noticed what a close resemblance this machine has with that of Pacinotti, the main difference being in the size of the electro-magnets and in the axis, which in Pacinotti's machine is vertical. Two sizes of this motor have been devised—one giving 145 kilogrammeters per second, the other 12.

THE BRUSH MACHINE.

This machine, which has a continuous current, is made in three types, being able, respectively, to feed 6, 16, and 40 arc lights; it is a high tension machine. It is composed of the three essential parts common to all dynamo-electric machines:

1. A revolving armature.
2. Electro-magnets for inducing the current, which are arranged in pairs on each side of the armature.
3. A commutator of peculiar form.

FIG. 31.—Section of ring.

The armature in the 16-light machine, which may be considered as the normal type, is 50 centimeters in diameter; it consists of a rectangular,

cast-iron ring, provided with grooves or depressions at right-angles to its magnetic axis or length (Fig. 31) which are wound full of insulated copper wire.* In this respect it differs from the Gramme armature, which is wound continuously, and resembles that of de Meritens. The thick parts have deep concentric channels cut in them, which diminish the weight, prevent the formation of induced currents and favor the dissipation of the heat, always developed by the rapid magnetizations and demagnetizations; in

FIG. 32

addition, this arrangement allows the armature to be brought very close to the poles of the electro-magnets. All the bobbins, as in the Gramme armature, are wound in the same direction, and, as the projections are wedge-shaped, the different helices of each bobbin are parallel. The wire used is .002 of a meter in diameter and about 270 meters long.

FIG. 33.

The interior ends of the wire of the bobbins diametrically opposite, are united, and thus the bobbins are grouped in four pairs, Fig. 32; the

*The most recent improvement in this machine is to build up the armature with small pieces of sheet iron instead of using the grooved cast iron; the general shape remains unaltered. This change is stated to greatly increase its efficiency.

exterior ends are free and are carried through the shaft of the armature, which is made hollow for this purpose, and are attached to the commutator. When the armature is wound it is supported by two brass arms on the central shaft, as shown in Fig. 33. Fig. 34 shows the completed armature ready to be placed in position; it revolves between the enlarged poles of four flat electro-magnets with rather large cores. These are wound with insulated copper wire .004 of a meter in diameter, the length of wire on each magnet being about 900 meters.

FIG. 34.

At one of the ends of the shaft is placed the commutator, consisting of a series of flat copper rings insulated from the shaft and from each other, equal in number to the number of pairs of bobbins, which, in the machine described, is four, the wire of each pair of bobbins being attached to one of these rings. Each ring is divided into two segments, A and B, Fig.

FIG. 35.

35, insulated from all the others on one side by a free space 5 millimeters wide, and on the other by a piece of copper, C, separated from the segments A and B by narrower free spaces. S is the insulating material.

The insulated pieces C serve to take out of the circuit a given pair of bobbins, when one of the brushes passes over it; at this instant the pair of bobbins thus insulated, not then producing any current themselves, are not traversed by the current produced by the three other pairs of bobbins.

The segment C occupies about one-eighth of the circumference of the commutator, and, as it passes in front of the two brushes at each revolution, the result is that during a complete revolution each pair of bobbins is in open circuit during two-eighths or one-fourth of the revolution; but, on account of the manner by which the brushes and commutator are arranged, the insulation of each pair of bobbins is produced at the instant when they traverse the neutral part of the magnetic field and, in consequence, add nothing to the current. By this ingenious arrangement the inactive and momentarily nearly useless bobbins are never in the circuit, from which it results that the current produced by the others does not traverse them at this moment and that they do not introduce in the machine an interior resistance more injurious than useful.

The electro-magnets are connected in tension, and are excited as follows:

The enlargement of the poles is such that three bobbins of the armature are at the same time opposite each pole; there is thus always one pair of bobbins beyond their direct influence. This is the pair which traverses, at this moment, the neutral part of the magnetic field.

FIG. 36

The mode of exciting the magnetic field is peculiar. Each pair of bobbins furnishes a current, which the commutators send alternately through the electro-magnets and through the exterior circuit, so that each bobbin, during a complete revolution, feeds alternately the magnets and the lamps.

The current takes the following course (Fig. 36): Suppose the attachment screw A to be the positive pole; the current then passes through the exterior circuit to the lamps, returns to B, thence to the brush M, traverses the pair of bobbins, 1-5 and 3-7, from which it receives the

electricity, arrives at the brush N, traverses the series of electro-magnets, thence passes to P, traverses the pairs of bobbins 2-6 and 4-8, from which it also receives electricity, and returns by the brush Q, to close the circuit at A. It will be seen that the pairs of bobbins are coupled for quantity in the general circuit, and that the exciting circuit is comprised in this circuit, the same as in the Gramme, Siemens, and others.

In addition to the attachment screws A and B, there are two other points of attachment, *c* and *d*, in connection with the circuit of the electro-magnets. In case fewer than the normal number of lights are in the main circuit, a box with variable resistances is placed between these points, forming a derived circuit between N and P, which absorbs a part of the current, which otherwise would pass through the wire of the electro-magnets; the interposed resistance is so regulated that the excitation of the magnetic field will be reduced in proportion to the work required of the machine.

A machine for sixteen lamps revolves at the rate of seven hundred and fifty revolutions per minute; the smaller machine for six lamps at nine hundred revolutions. These velocities are less than those required in most dynamos.

The brushes are flat and flexible copper strips, cut in eight tongues, in order to insure good contact with the commutator; each brush is wide enough to rub against two rings corresponding to two pairs of bobbins of the armature; consequently, though in each pair of bobbins, taken alone, the current is interrupted twice in each revolution, the main current is never interrupted.

The machine for feeding thirty-two lamps is identical in principle with the one just described; it only differs in size and in having twelve instead of eight bobbins.

From measurements made in the workshops of the telegraph supply company, Cleveland, Ohio, the electro-motive force of the sixteen-light machine was eight hundred and thirty-nine volts. The intensity of the current did not exceed ten webers. The expenditure of useful work was about one horse-power per light.

This high electro-motive force allows the use of long and resisting circuits. In London thirty-three lamps were placed in series for a distance of about three or four miles. Such currents are not without danger, and require the most careful insulation.

SIEMENS DYNAMO.

The principle is very similar to that of the Gramme machine, but the revolving armature is made differently, and consists of a soft iron drum with spherical ends, enveloped on the exterior with insulated copper wires running longitudinally. This armature revolves between the poles of

electro-magnets, so that all its parts are in the magnetic field, except the hemispherical ends. An early form of machine, exhibited in Vienna in 1873, is shown in Figs. 37 and 38.

FIG. 37.—Section through shaft.

A wooden base is fixed to a frame, *m m*, supporting electro-magnets *E, E, E, E*, with their similar poles *N, N, S, S*, opposite to each other, and two posts, *D* and *D 2*.

FIG. 38.—End elevation

The shaft *C* is rigidly connected with the thick iron cylinder *as na*, and is fastened to the posts *D D2* by screws. The drum, on which the copper is wound, is supported by the disks *ab ed*, which are extended into two hollow shafts turning in the bearings of the supports *F F2*.

A pulley, *Q*, fastened to the disk *ed* transmits the movement of the motor to the drum; the shaft of the disk *ab* carries the commutator.

The electro-magnets are made of light, flat, iron bars, and their poles envelope two-thirds of the circumference of the revolving armature.

When the drum is revolved the helices pass as near as possible to the poles of the electro-magnets and to the interior cylinder, which remains

fixed. The poles NN SS develop opposite poles in the interior cylinder, and thus there is a powerful magnetic field through which the drum revolves, and a strong induced current is produced in its helices.

FIG. 39.

Fig. 39 shows the arrangement of the wires in relation to the commutator or collector, being a theoretical view of the attachment of the wires. The light groups of wires which cover the drum have their 16 ends

FIG. 40.

marked by the numbers 1, 2, 3, 4, 5, 6, 7, 8, 1', 2', 3', 4', 5', 6', 7', and 8'. The first group commences at 1 and ends at 1'; the second group commences at 2 and ends at 2', and the same with the others. The signs

+ and — show the direction of the current which issues from each group taken by itself, for a determined position, when the drum turns in the direction of the arrow. The sectors *a, b, c, d, e, f, g,* and *h* form the collector, against which rub the brushes for receiving the current, which are placed at *g* and *e*, at right angles to the line joining the poles N and S.

The current generated is always in the same direction ; its intensity depends upon the velocity of revolution.

The later machines contain certain improvements in detail, which are sufficiently well shown without description, in Fig. 40.

SIEMENS DYNAMO FOR REFINING METALS.

This machine was especially designed for chemical decompositions, which require a current of large quantity and feeble electro-motive force. To accomplish this the magnets and armature are wound with copper bars instead of wire, insulated with asbestos, which would not be injured should the machine heat.

Fig. 41 shows the details ; these copper bars are wound but once around

FIG. 41.

the magnet and the armature ; their junctions are both bolted and soldered together, to insure good contact. The internal resistance is .0007 of a Siemens unit, the intensity of the current is about 800 webers, and the electro-motive force is about equal to three Daniell cells. These machines have been in use since 1879 at the royal copper mines, at Oker, in Germany, to deposit the copper contained in the water.

Three machines are used, each depositing copper in ten or twelve vats. Each vat furnishes in twenty-four hours 25 kilograms of pure copper, at an expense of from 8 to 10 horse-power for each machine.

These machines are only useful when the impurities in the copper solution do not exceed 2 per cent., on account of the polarization which takes place in the vats, which requires a greater amount of work from the machine to overcome it.

The Siemens alternating current machine has been ingeniously altered by Mr. Alteneck, the engineer of the house of Siemens & Halske, to a continuous-current machine. The former machine is composed of two circular rows of electro-magnets, having opposite poles, between the magnetic fields of which revolve galvanometric bobbins without iron cores.

Fig. 42 shows two of these bobbins. N, S, and N are the poles of the electro-magnets, situated at one of the sides of the machine. These poles are alternately north and south, and opposite each of them is a pole of contrary name, so that the successive magnetic fields are inverse. The bobbins without core are shown at the moment when they are half in one magnetic field and half in another. At this moment there is developed in one half of the wire an ascending and in the other half a descending current, and these currents unite. When the bobbins are entirely included in the corresponding magnetic fields, no current is produced, and, as the bobbin moves into the next magnetic field the current is resumed in a contrary direction to that immediately preceding it, and so on.

FIG. 42.

The bobbins are so coupled that at the same instant the current is in the same direction in all, and the ends of the wires are led to two collectors, from which the brushes collect, in consequence, an alternating current.

The modification of Mr. Alteneck is based on the use of a number of bobbins which is less than the number of magnetic fields. In place of collecting currents which are generated at two fixed points, those currents are collected which are produced successively at different points of the machine.

Fig. 43 shows, theoretically, the working of the machine; the ten rectangles, C, C, C, C, C, C, C, C, C, and C, alternately black and white, rep-

represent the magnetic fields of inverse direction, as they are arranged in the Siemens alternating current machine. The eight disks, F, F, F, F, F, F, F, and F, also white and black, represent the bobbins alternately wound in opposite directions, and which revolve in the magnetic field. The circle marked with the numbers 1 to 8 is designed to represent the commutator, to be mentioned further on.

FIG. 43.

In this diagram it will be seen that the parts of the machine, though not occupying their places, retain their relative positions. The bobbins being connected, as shown in the figure, and forming a continuous circle, let us suppose that the disk which carries them causes them to revolve in the direction of the hands of a watch.

It is easy to see that, in consequence of the alternation of the poles of the electro-magnets and of the alternate winding of the bobbins, all the bobbins which approach a magnetic field of the same color generate in the circuit a current in the same direction, and all those which approach a magnetic field of an opposite color produce a current inverse to the first.

On examining the figure, and supposing all possible positions of the bobbins,* a line, *op*, will always be found dividing the series of these bobbins into two halves, each traversed by a current of opposite direction. The distribution will, in fact, be like that of the Gramme ring, and it will be seen that, with this arrangement, in order to collect a continuous current, it will suffice to have two contacts, which are always at the extremities of the line *op*, whatever may be the position of this line.

* An easy way to do this is to trace the central part of the figure and then to lay it on the figure in different positions.

To accomplish this result a commutator is used analogous to that of ordinary dynamos, and shown in detail in Fig. 44.

For a machine with ten pairs of electro-magnets and eight bobbins, this commutator is composed of forty insulated plates, *tt*, which, in the diagram, Fig. 43, are represented by the forty spaces numbered from 1 to 8. These plates are divided into eight groups, the first including all those marked 1, the second all those marked 2, and so on.

FIG. 44.

All five plates of each group are connected by means of the wires *dd*, Fig. 44, with the same metallic ring *r*, so that the axis carries eight similar rings, each communicating with five plates. Besides this, between the successive bobbins issue wires from the conductors which connect them, the points of attachment of these wires being indicated on the diagram, Fig. 43, and designated by the numbers 1 to 8. Each of these wires communicates with one of the groups of plates previously described. Wire No. 1 communicates with group 1, wire No. 2 with group 2, and so on.

The current is taken up on two points on the cylinder, diametrically opposite each other, by means of rubbers similar to those of other machines. These points of contact are designated in Fig. 43, by two arrows and the signs $+$ and $-$.

If the machine is considered as in the position shown in the figure, it will be seen that, for such position, the ends of the line *op* correspond

with the wires 3 and 7, which accordingly take, the one a positive and the other a negative tension. But these wires communicate, one with all the plates 3, the other with all the plates, 7, of the commutator; and it will be seen that the rubbers at this moment are exactly on a plate, 3, and a plate, 7, and, in consequence collect the current produced.

FIG. 45

A like result will happen for any other position of the revolving bobbins; so that the rubber $+$ will be always at a positive, and the rubber $-$ at a negative potential, and a continuous current will be collected.

It will readily be seen that the number of bobbins and of the magnetic fields may vary. One arrangement in which the number of bobbins is doubled, having the number of magnetic fields unaltered, is shown in Fig. 45; in this case the bobbins are arranged one above the other, but so as to only half cover each other.

Fig. 46 is a diagram of a machine so arranged; the bobbins are no longer connected in a continuous series, but the connection is alternating; the commutator in this case has eighty plates. This arrangement has the advantage that, in consequence of the constant reaction of the bobbins on

FIG. 46.

the poles of the electro-magnets, the working of the machine is better and its running easier. Besides, the commutator having more plates the sparks are less: Mr. Alteneck states that this machine has, in the first place, the same advantages as the alternating current machine, namely, constancy of the magnetic fields; absence of an iron core in the bobbins, which suppresses the changes or displacements of pole and the losses of energy consequent upon a heating of the cores; facility of winding; possibility of insulating perfectly the wire of the bobbins from the metallic parts of the machine; and, finally, the slight heating of the wires, in comparison with the current produced.

Although the alternating-current machine has the advantage of simplicity, and each kind of machine is specially adapted for certain work, yet the continuous-current machine alone can be employed for certain purposes, such as electro-metallurgy, the electrolytic extraction of metals, the electrical transmission of power, telegraphy, etc.

One of the machines constructed on the principle just described can supply four lights of 700-candle power each, with an expenditure of 7 horse-power.

THE HOPKINSON-MUIRHEAD DYNAMO.

This machine bears a certain analogy to the preceding, and so will be next described.

Fig. 47 shows, in section, the left-hand side and, in elevation, the right-hand side of the machine. Fig. 48 is a section perpendicular to the axis of rotation. The exterior view of the machine resembles a metal drum of rotation. The exterior view of the machine resembles a metal drum pierced with openings, outside of which are seen, on one side the pulleys, on the other the commutator. This drum is closed at each side by two thick disks of cast-iron, C, forming the base of the electro-magnets. The latter, which are fixed, are ten in number on each side; their cores, B, B, have a trapezoidal cross-section, and the bobbins D, D take a similar form. Besides, to avoid the formation of induced currents, these cores are traversed by deep grooves, seen at B, filled with insulated sheet iron.

FIG. 47.

The coupling of the wires of these electro-magnets is made as in other machines, so that the poles are alternately north and south, and that each north pole is opposite a south one.

The armature is constructed as follows: around a pulley fixed on the axis is coiled a band of sheet iron, 1 millimeter thick and from 4 to 5 centimeters wide, and asbestos paper, so that the asbestos separates the successive layers of iron from each other. When a sufficient thickness has been obtained, radial holes are drilled through to the pulley, through which screw bolts are inserted, so as to hold all tightly to the pulley. Radial slots are then cut in the ring thus formed, on both sides, thus forming cores, around which insulated wire is wound.

Up to this point, apart from the form and special construction of the electro-magnets and revolving armature, this machine differs but little

from others. The principal difference is in the manner of collecting the currents. In fact, the apparatus is composed of twenty plates, arranged like those of the Gramme collector, but really constitute a commutator. To understand its arrangement, let us first consider only the front movable bobbins. The two wires issuing from each of these bobbins are attached to two contiguous plates of the commutator; ten rubbers, fixed on ten rods, which are carried by the circumference of the drum and are not shown in the figure, press against the commutator. Each of these rubbers is double; that is to say, it is formed by two distinct springs, one of which just touches the edge of a commutator plate, when the other touches the same plate in the middle. The number of rubbers being only

FIG. 48.

one-half that of the commutator-plates, only touch the latter by two and two. If the rubbers were single any two neighboring rubbers could never touch two contiguous plates; but, on account of the separation of each of them into two springs of different adjustment, the two rubbers touch both plates for a certain time. Thus a given pair of rubbers is in communication with each of the revolving bobbins. This communication will take place at the moment when the current is at its maximum in the

bobbin, and, as the collected current will always correspond to bobbins in the same situation opposite the magnetic field, it will always be in the same direction for the same pair of rubbers. Each pair of rubbers will become then a distinct current generator, and the machine can furnish five distinct circuits. One of these circuits is employed to excite the inductors and the other four can be used separately or altogether.

The preceding description assumed that there were bobbins only on one side of the revolving disk, but, in reality, the wires of the bobbins on the other side are connected to the wires of the first set of bobbins, and the winding is such that at the same moment the current is in the same direction in all the bobbins coupled together. The manufacturers state that this machine, with a velocity of five hundred revolutions per minute, will furnish a current with an electro-motive force of about 50 volts.

The following advantages are claimed:

The electro-motive force is not so high as to be dangerous.

The lamps can be mounted in independent circuits.

The machine does not heat sensibly in any of its parts.

It works at a moderate velocity.

It would seem that the use of so many rubbers would be troublesome, and the collection of currents not being continuous, strong sparks would be produced.

This machine can be readily modified so as to give alternate currents, in which case but two rubbers would have to be used.

THE WESTON DYNAMO.

This machine resembles both the Gramme and the Siemens machine, having electro-magnets similar to those of the former and a modified Siemens armature. Its construction is as follows:

The general appearance of the machine is shown in Fig. 49. The inductors are six horizontal electro-magnets, cylindrical in form, whose poles unite in two polar pieces, one placed above the other below the armature.

The coils of these magnets are connected in series and traversed by all the current produced by the machine.

The armature makes about nine hundred turns a minute. The polar pieces which surround it, instead of being continuous, are divided by cuts forming a series of teeth, T, T, T', T', Fig. 50, which shows the polar pieces with the coils and end plates of the machine removed. It will also be noticed that the space between the two polar pieces is greater in the middle than at the ends, the length of the teeth diminishing toward the center. According to Mr. Weston, this arrangement gives more regularity to the current, the induction on the coils of the armature being

made from the center toward the ends, and *vice versa*, instead of taking place simultaneously along the whole length of one of the elements of the armatures. The cuts in the polar pieces are intended both to prevent the formation of induced currents and also to cool, by ventilation, both the polar pieces and armature.

FIG. 49.

The latter is of a special construction. The cylinder on which the wire is wound, instead of being a single piece of iron, is formed of a series of thirty-six sheet-iron wheels, having the form shown in Fig. 51. These wheels have each sixteen teeth, having between them sixteen openings.

FIG. 50.

FIG. 51.

They are threaded on the axis and separated by rings of the same thickness as the wheels. Two full disks are placed at the ends, and the armature resembles a cylinder with hemispherical ends.

In the slots formed by the teeth the wire is wound in the same way as

in the Siemens armature, except that in each group of wires is contained one of the slots. This arrangement assures good ventilation, since the armature contains $16 \text{ by } 36 = 576$ openings. As the hemispherical ends are also pierced, a continuous circulation of air is established in the apparatus.

The commutator is similar to that of Gramme, only the plates have a slightly helicoidal shape, and are only separated by air spaces instead of these spaces being filled with an insulating material. This helicoidal arrangement is adopted in order that the collecting brushes may always be in contact with two plates, and thus give more regularity to the current. The commutator is clearly shown in Fig 49.

The brushes are formed of a dozen leaves of brass, with cuts in their ends; they are mounted on a movable support, in order to give them the adjustment desired.

This machine and a modified form are used to feed the arc and incandescent lights of the United States Electric Light Company.

THE MAXIM DYNAMO.

This machine closely resembles that of Siemens, but there are differences of detail. (See Fig. 52.)

FIG. 52

The collecting brushes are automatically adjusted, as described under the head of "Incandescent Lamps;" the radial pieces forming the collector, instead of being straight, are in the form of an elongated V, thus assuring the contact of the brushes with several sections of the collector at the same time.

The brushes are composed of thin brass leaves and do not score the collector like those made of bundles of wire.

The armature is composed of two distinct parts, mounted on the same axis; these two parts can form at will two distinct machines or a single one, and the two halves can be grouped in tension or in quantity by a commutator placed on top of the machine. This armature revolves at the rate of nine hundred turns per minute. The generator of type No. 20 can feed a single light of 20,000-candle power, or 85 incandescent Maxim lamps of 25-candle power each. It requires 10 horse-power to drive it.

THE GULCHER DYNAMO.

This machine is constructed on the principle of the Pacinotti ring, and is specially devised to furnish currents of large quantity and low electro-

FIG. 53

motive force; for this purpose, the resistance of the armature and of the electro-magnets had to be reduced to a minimum. It consists of four flat electro-magnets wound with an insulated copper-wire rope, as solid wires of large diameter could not well be coiled. The corresponding poles of each pair of electro-magnets placed opposite each other are connected to-

gether by a **U**-shaped trough, so as to surround the greater part of the periphery of the armature and thus subject it to a strong inductive action. (See Fig. 53.) The section of the ring is wedge-shaped, in order to utilize as much as possible the coiled wire. The mechanical arrangement of the armature is such as to keep it cool, as it, with the **U**-shaped polar pieces, forms a powerful fan. Much greater contact surfaces are given to the commutator than is usual in other systems, and is necessary on account of the low-tension currents produced. There is almost a total absence of sparking. As the armature is encircled by four pairs of poles, there are four sets of brushes connected with the commutator.

The two positives are joined together, also the two negatives, each combination thus forming one large brush, one $+$ the other $-$. It will be seen, therefore, that the internal resistance of the armature, measured through these brushes, would be only one-sixteenth of that of the whole armature. The arrangement of these brushes is shown in Fig. 54, the larger diagram showing the armature **A**, the pole pieces **N S**, and brushes $+$, $-$; the smaller showing how the brushes are connected.

FIG. 54.

The electro-magnets are also so connected that all the ends nearest the pole-pieces, Fig. 54, are joined together and carried to the brush $-$, and the remaining ends to the terminal $+$, the other brush being connected to the terminal $-$. This arrangement reduces the total resistance of the electro-magnets to one-eighth of that of a single one. In the figure, 1 is the section of the armature, 2 the **U**-shaped poles, 3 the commutator, 4 the brushes, and **E** the electro-magnets.

The armature revolves at the rate of nine hundred turns per minute, and the machine gives a light of about 813 candles per horse-power. Since the Exhibition these machines have been improved and better results obtained, the light being from 1,000 to 1,400 candles per horse-power.

With this machine the lamps are mounted in a derived circuit and the

system automatically regulates the horse-power required for any number of lamps. This will be fully explained when the Gulcher lamp is described.

THE SCHUCKERT DYNAMO.

This machine closely resembles the Gramme, the principal difference being that the armature, instead of being cylindrical, is flat, running in a narrow magnetic field produced by four horizontal electro-magnets, which are included in the main circuit of the machine. The armature is built up of a number of thin disks, insulated from each other and covered with coils. The pole-pieces consist of flat, segmental plates, these plates being parallel to those of the ring and perpendicular to the axis on which it rotates, and in this respect resembles the Gulcher dynamo.

The current generated is of very high electro-motive force, and, in consequence, the generator may be placed at a considerable distance from the lamps or the lamps from one another.

At the Exhibition this machine was used to feed the Joel candles and the Pilsen lamps.

The following table shows the results of some tests made at Paris with this dynamo :

Machine resistances.	Ohms.	Revolutions per minute.	Horse-power.	Resistances.		Webers.	Volts.	
				Exter-nal.	Total.		Total.	Exter-nal.
				Ohms.	Ohms.			
Armature	5.7	700	5.5	27	40	9	360	243
Magnets	6.6	.....	5.0	30	44	8	351	240
Total, cold	12.3	.....	4.5	35	49	7.4	362	259
Total, warm	14	.....	3.8	40	54	6.5	351	260

At seven hundred and twenty revolutions this machine feeds six Pilsen lamps with arcs 2.5 millimeters wide, and 7.5 to eight webers of current each, 4.5 horse-power being required.

THE EDISON DYNAMO.

The Edison generator, which, with its driving engine, weighs 17 tons, is chiefly remarkable as regards novelty of construction and general arrangement of the armature. This armature, which is shown in Figs. 55 and 56, the latter being a section, is composed, in the first place, of an iron axis, on which is a wooden cylinder; the latter is covered with a thick, iron tube, formed of a series of very thin, flat, iron disks separated by paper. This tube is terminated at its extremities by two large iron cheeks which grip the plates laterally. Arranged longitudinally around the iron cylinder are a number of straight copper bars of trapezoidal cross-section and well insulated from each other by prepared brown paper; these

bars take the place of the wire wound on the armatures of ordinary machines. A number of well-insulated, flat, copper rings are strung over the central shaft at each end of the armature; there are half as many rings on each side as there are bars; *e. g.*, if there were fifty bars, then there would be twenty-five rings on each side of the armature.

FIG. 55.

FIG. 56.

The left-hand rings are connected to the left-hand ends of the copper bars, two bars being connected to each disk; and the arrangement is such that in every case two bars which are diametrically opposite to one another are connected by a ring. The right-hand end of one of the two bars to which we have just referred is connected to a ring on the right-hand of the armature; but this latter ring, instead of being also connected to the second of the two bars alluded to, is connected to the bar next to it, while the opposite end of this bar is attached to a fresh ring at the other end of the armature, and so on, until all the bars have been included in one continuous electrical circuit.

The iron core is thus coiled by a continuous circuit formed of the copper bars and rings; these bars and rings being of comparatively large dimensions, the total resistance of the circuit is very small (.008 ohms between the commutator brushes); moreover, the resistance of the inactive portions of the circuit, namely, the copper rings, is very trifling.

In the large machine there are one hundred and thirty-eight bars in the

armature, the active length of each of the bars being $3\frac{1}{4}$ feet. The copper rings are connected to one hundred and thirty-eight insulated copper sectors, which form a cylindrical commutator of the ordinary form. The contact brushes are arranged in the usual manner. The engine which drives the armature forms part of the whole apparatus, and is of 125 horse-power.

FIG. 57.—Edison's small dynamo.

When the machine runs at the rate of three hundred and fifty revolutions a minute an electro-motive force of about 100 volts is obtained.

In the smaller machine the magnets are vertical; in the larger machine the horizontal arrangement is adopted.

FIG. 58.—The Edison dynamo, large size.

THE ARAGO DISK DYNAMO.

This machine was exhibited in the American section. There are two types, the simplest of which, shown in Fig. 59, comprizes two electro-

FIG. 59.

magnets, E E, each having one end attached to the iron frame of the apparatus and the other ends opposite each other, the magnets being so wound that the polarity of each pair of magnets facing each other is of an op-

posite nature. The magnets are provided with sector-shaped pole pieces, which embrace on each side the greater part of the revolving armature. The latter is formed of six bobbins, without iron, of the shape shown in Fig. 60. The wire FF is wound around a piece of wood, B, and the bobbins thus formed are held between two disks carried by the axis, a

FIG. 60.

double ring of copper, C, forming the circumference. The six bobbins are all wound in the same direction, but are coupled up in such a way that a current passing through them in series would circulate through them in opposite directions. From the points where they are attached together conductors are led to each of the six plates of a collector analogous to that of the Gramme. There is an induction coil analogous to that of the Siemens alternating-current machine, but with a Gramme collector.

The brushes are arranged like those in most other machines, and, in certain cases, the plates of the collector present a special arrangement, which, at a given moment, eliminates from the circuit the pair of bobbins in the neutral line, so that the inactive pair of bobbins is cut out from the circuit. It will be remembered that there is a similar result obtained in the Brush machine.

One peculiarity of this machine is the absence of any noticeable external magnetic field.

The second type, shown in Fig. 61, has six opposite pairs of poles, and, in consequence, six alternate magnetic fields. The armature is made in the same way as the preceding and contains eight bobbins without iron. The commutator is composed of twenty-four plates.

The principle by which the current is rendered continuous is exactly the same as in the Hefner-Alteneck machine. The two rubbers are always in contact with the two plates corresponding to the line which divides the armature in two equal parts, traversed by inverse currents. The only difference in arrangement between this and the Hefner-Alteneck machine is, that in the latter the number of bobbins is less than the number of magnetic fields, while the contrary is the case in the machine being described.

The armature is different from that of the type first mentioned; each of the bobbins is in two parts. The induced current, generated in the most important of these parts, is thrown into the circuit of exterior work.

The induction produced in the other portion creates a current that excites the electro-magnets. On account of this arrangement the collector is divided into two distinct parts, each corresponding to one of the circuits just mentioned.

FIG. 61.

The brushes L L are mounted in a special way; their supports are fixed on a ring, A, outside the frame of the machine, and the brushes are carried by springs held by rods fixed to the ring.

It will be seen that this machine is a self-exciting generator, the arrangement adopted involving the use of two sets of brushes and two commutators. The ring on which the brushes are mounted can be turned around through a considerable angle, so as to adjust the brushes to the position of highest efficiency.

It is stated that the larger of these two machines, with a velocity of one thousand revolutions per minute, and at an expenditure of from five and a half to six horse-power, can feed from ten to twelve arc lamps of average intensity. Reliable data, however, are wanting.

Probably the most curious looking generator in the Exhibition was this machine. It is the joint design of Prof. C. Jurgensen and Dr. P. L. V. Lorenz, both of Copenhagen. In addition to its form, it has the peculiarity of having an electro-magnet inside the revolving armature. This feature was adopted in the early form of Siemens' machines, but was soon abandoned. Professor Jurgensen claims that Siemens' system of winding the interior electro-magnet was faulty, and that the method he has adopted has greatly increased the efficiency of the machine.

The machine consists of two electro-magnets, $A A^1$ (Fig. 63), combined

FIG. 62.

so as to form a horseshoe-magnet, with extended pole pieces, surrounding a cylindrical armature like Gramme's, but wound differently. The number of layers of wire on the electro-magnets is increased toward the poles, so as to intensify the magnetic field without adding too much to the resistance.

The armature consists of a number of thin iron rings, $B^1 B^1$, placed side by side and insulated from each other, to prevent the creation of induction-currents. By this arrangement very wide armatures can be constructed; the sections are held together by bolts passing through them, as shown.

Around the ring thus formed the wire is coiled, as shown in Fig. 63, to complete the armature, which is mounted as follows: To the outer sections of the ring-studs B^3 are secured insulated rings, $G^1 G^2$, provided with spokes, but each of these two rings is of a somewhat different form; G^1 has a small boss, to which is screwed the sleeve, which enters the bearing M of the main standard F . The other boss, G^2 , is formed with a long sleeve passing over and secured to the driving-shaft H . The spokes connecting the ring G^1 with the boss, are provided with wings, for the purpose of creating an active current of air and keeping the various parts of the machine cool.

Motion is given the armature by the driving-pully I, mounted on the shaft H, which terminates flush with the inner face of the ring G². The outer electro-magnets A¹ A¹ are of the curved form, and are bolted to the base-plate A². In order to check vibration and increase the steadiness of

FIG. 63.

the machine the tops of the pole pieces are held together by a brass plate, shown at the top of Fig. 62, and by two insulated standards, L L, underneath.

To complete the machine, the space within the cylindrical armature is filled with a second electro-magnet, as shown in Fig. 63. The magnet is carried at the end of the shaft E, passing through the standard F and the sleeve of the ring G¹, which revolves around it. It is formed of two bar-magnets, at right angles to each other, wound as shown in the section; at the ends of these magnets are the pole pieces *d* (Fig. 62) curved so as to present their surface to nearly the whole inner side of the armature. The north and south poles of these magnets are opposite the similar poles of the outer magnets.

This interior magnet is more clearly shown in the annexed sketch (Fig. 64). The commutator is shown at C (Fig. 63), and consists of a series of L-shaped copper bars, one face of which rests on the sleeve to which the driving-shaft is secured, the other face butting against the ring G²; the section shows two of these commutator bars. They are insulated from the sleeve and ring, and also from the large washer J, by which they are fastened to the ring G². The collecting brushes are not shown, but they are of the usual form, placed on the bracket K, and are capable of adjustment; they are either four or two in number, so that the machine can be used as a self-exciter, or the field-magnets can be actuated by a separate exciter.

To sum up, the special features of this machine are : The application in dynamos of an electro-magnet within the revolving armature, with or without the use of external electro-magnets ; the use of annular armatures made up of a series of sections or narrow rings, insulated from each other ;

FIG. 64.

the special mode of ventilating and cooling the machine by means of the fan or wings attached to the ring at the end of the armature, and the special form of the outer electro-magnet.

The inventors claim that this machine, for its size, is the most powerful yet made, but no data were furnished at the Exhibition.

In August, 1882, Messrs. Ayrton and Perry made a report on the working of this machine, from which the following is extracted :

Tests were made of the current and electro-motive force produced by the machine running at different speeds: 1st, when two arc lamps were in circuit ; 2d, when one arc lamp was in circuit ; and, lastly, when various resistances were introduced, and the following results were obtained :

Number of revolutions per minute.	Current in ampères.	Electro-motive force in volts between the terminals of machine.	Approximate total electro-motive force of the machine.	Resistance in the external circuit in ohms.	Remarks.
800	17.3	78.3	126	.....	Two arc lamps burning in circuit.
840	18.1	97.2	148	.....	Do.
550	15.4	58.0	101	.....	One arc lamp burning in circuit.
620	14.3	65.3	106	4.5	Do.
610	16.4	54.5	103	3.3	Do.
620	20.7	43.8	102	2.1	Do.
560	24.2	28.1	97	1.2	Do.
630	25.8	29.0	103	1.2	Do.

If the last set of observations be reduced all to the same speed, six hundred and twenty revolutions per minute, the total electro-motive force becomes—

106 volts.

105 volts.

102 volts.

107 volts.

103 volts.

From this it is seen that for currents in the field-magnets, varying from 12 to 26 ampères, the total electro-motive force is nearly constant, which shows that for the smaller current the field-magnets are already saturated. Hence, less wire might advantageously be used on these magnets, producing a resistance less than 1.1 S. U., which, we are informed, was the resistance of the internal and external field-magnets together; that of the revolving armature being, we are informed, 1.75 S. U.

The greatest power electrically developed by the dynamo during the preceding experiments was 3.6 horse-power, and the greatest horse-power usefully, electrically developed, that is developed in the external circuit, was 2.4.

THE JABLOCHKOFF ALTERNATING-CURRENT DYNAMO.

Two of these machines were shown, one with sixteen, the other with thirty-two bobbins; a description of the former will show the principles on which it is constructed.

The inventor's object was to have revolving electro-magnets, which should induce a current in a series of fixed bobbins outside the magnets, these latter being always visible, divided into independent parts and separately reparable in case of accident, without stopping the machine or interfering with its working. It may be compared to a Gramme machine turned inside out.

The inductor consists of eight electro-magnets of helicoidal form. To avoid the difficulty of forming these magnets from a single piece, they are made in a series of star-shaped pieces of sheet-iron, from 3 to 4 millimeters thick, with eight branches—see Figs. 65 and 66—and pierced with a

FIG. 65.

FIG. 66.

hole in the center; these are mounted on an axis, one against the other; and to each a slight angular advance over the preceding one is given: by this means the desired spiral surface is obtained. The eight branches are connected by locking-bolts passing through the stars; and the steps formed by the angular advance are reduced to a continuous surface by filing. The core thus formed is solid and compact and not likely to be

injured by the action of centrifugal force. On the inclined surfaces of the core coils are wound, through which the current of the exciting machine circulates; this is ordinarily a direct-current Gramme of the usual work-shop type. The coils are wound in such a way as to give contrary magnetization to the successive poles.

The fixed coils receiving the induced current are made of a series of iron plates, 1 millimeter thick, placed together so as to form a flat core. The annexed sketch Fig. 67 shows the shape of these plates. The wire is

FIG. 67.

wound around them in a direction perpendicular to their length. The form and arrangement of these coils are shown in Figs. 68 and 69. They

FIG. 68.

FIG. 69.

are fixed by two copper armatures held at their ends by two rings attached to the frame. Their dimensions and those of the wire covering them are so calculated that each of them corresponds to a normal Jablochkoff candle of 4 millimeters diameter, so that a generator with sixteen coils is also a 16-light machine.

If one of these coils should become disabled, it can easily be removed and replaced by a spare one without stopping the machine, by simply cutting out the lamp corresponding to the magnet being shifted.

One of the advantages of the arrangement adopted for the inductor is, that a small angular movement corresponds to a large displacement of the magnetic pole, which allows the use of moderate velocities. The 16-light machine has a velocity of 750 revolutions, to feed 16 lights of from 50 to 55 careels.

The 16 coils are connected in four series of four coils each, thus making four circuits, each of which supplies four Jablochkoff candles; the re-

sistance of each coil is .3 of an ohm ; the resistance of each circuit is thus 1.2 ohms ; about 14 horse-power is required.

The 32-light machine, Fig. 70, differs only in a few minor details from

FIG. 70

the one just described ; the coils are fixed in a somewhat different manner, and are covered with a perforated envelope of copper, to provide a passage for the air, which is driven out rapidly by the helicoidal electro-magnets. The dimensions of this machine are—

	Inches
Length of generator.....	48.00
Length of shaft with pulley.....	66.00
Height.....	61.00
Diameter of circle described by the coils.....	33.08
Clear distance between the coils and the magnets.....	64

ELECTRIC LIGHT FOR MILITARY PURPOSES.

LIST OF APPARATUS.

Santter and Lemonnier's lenticular projector, large size.	Santter and Lemonnier's projectors, for ships' boats.
Santter and Lemonnier's projector, mounted on a cart.	The Mangin projector.
Small Gramme machine, for hand power.	The Mangin projector, mounted on a cart.

APPLICATION OF THE ELECTRIC LIGHT TO MILITARY OPERATIONS.

The first idea of the application of the electric light dates back to the Italian war, in 1859. A society was formed to use, at this epoch, the Grenet battery, with a view to this application, and a wagon could be seen in the streets of Paris carrying a battery and an electric light. The peace of Solferino put an end to these experiments, which, with the means then known of producing electricity, could have had no practical results.

In 1867, at the Universal Exhibition in Paris, Austria sent a metallic parabola of large size, having an electric light in its focus; near by were shown several drawings showing different applications, which could be made with this apparatus, for the attack or defense of places, or for other military operations.

The first practical applications of which we have knowledge date from the Franco-German war at the siege of Paris. No remarkable result was obtained at this epoch. This was partly because, during this military operation, the artillery attacks were usually at long range, and hand to hand attacks were extremely rare, and partly because the appliances used to produce the light and to project it to a distance were out of proportion to the range of the artillery. The electricity was furnished by batteries, and by the Alliance machine.

The Gramme machine was then scarcely invented, and the optical apparatus were projectors, parabolic or spherical reflectors of small diameter, a few more or less ingenious combinations of lenses, and a lenticular projector.

These efforts showed besides that it was necessary to have movable apparatus able to operate outside the *enceinte* of the place and to accompany certain operations. To accomplish the above, portable batteries were devised, which, though very ingenious, were still too cumbrous for ordinary use.

If the electric light employed under these conditions did not appear to the besieged of great utility, it is probable that the besiegers did not think the same, for, from this epoch, the Germans studied it and there could be

seen in 1873, in their section at the Vienna Exhibition, an apparatus for the projection of the electric light, adapted to military use and fed by a Siemens dynamo-electric machine, while near by Messrs. Sautter and Lecomte exhibited in the French section a projector for the navy, lit by a Gramme machine.

The preceding year Denmark and Russia were using analogous machines, which France had furnished them for lighting passes defended by torpedo-boats.

From this epoch earnest work has been done, and the results recently obtained by a commission of French officers, at the Fort of Mont-Valerien, permit us to count electric lighting among the useful means of defense, with which fortified towns, forts, and army corps should be supplied. The following are some of the results obtained :

By using the Gramme machine with four columns, giving, coupled in tension, 1,500 carrels, and coupled in quantity 2,500 carrels, movements of troops, horses, and carts are rendered visible to observers at the side of the optical apparatus at a distance of 5,000 meters, and at 2,700 meters the observer can distinguish soldiers and recognize that they are fencing with the bayonet.

If one remarks that, for an observer placed near the projector, the light travels twice the distance which separates him from the locality lighted, and that the intensity of the light reflected is inversely proportional, no longer, to the square of the distance, but to its fourth power, exclusive of the atmospheric absorption, which, in addition, acts as if the distance were doubled, it will be recognized that the range of the sight can be notably increased, by placing the observer at 1,000 to 1,500 meters from the point to be lighted, leaving the apparatus 3 or 4 kilometers in the rear, guarded from the enemy's artillery.

We will call special attention to this peculiarity of the Gramme machine, namely: that by a simple movement of the commutator it can be coupled for tension or for quantity; coupled for quantity, the light is doubled, which is convenient when an intense light is required, or when the object to be lighted is distant, and is indispensable when the weather is foggy; coupled for tension, the current can be carried a great distance, even a kilometer from the machine, and still give a light of 1,000 to 1,500 carrel lamps, by increasing the number of revolutions of the electric machine, in proportion to the distance at which it is desired to produce the light. The electric machine can then be located in a fixed and central position, around which the projection apparatus can be moved in a radius of 1,000 meters. For this purpose the apparatus is mounted on a light cart easily transported.

The apparatus employed by the French Government, for the lighting of fortified towns and for the defense of coasts, is composed of a Gramme

machine, a Mangin projector, a Brotherhood engine, and a field boiler. (See Fig. 71.)

The Gramme machine has flat electro-magnets; it gives, coupled for tension, a light of 2,500 carrels, and coupled for quantity, a light of 4,500 carrels. This machine makes two hundred and fifty to three hundred revolutions per minute, coupled for tension, and five hundred revolutions coupled for quantity.

The entire apparatus—electric machine, motor and boiler—can be installed as a fixture upon a masonry pier, or better, as shown in the figure,

FIG. 71.—Portable engine, boiler, and dynamo machine.

mounted on an iron wagon with four iron wheels. The boiler in this latter arrangement has a movable chimney, sufficiently low to pass under the arches of the traverses.

The projector employed is that of Colonel Mangin. It is placed on a low, light cart, which allows it to be taken to the most suitable point on the fortification or of the coast. This projector is composed essentially of a concavo-convex glass mirror, with spherical surfaces of different radii.

Between the mirror and the focus is interposed a concavo-convex lens, of which the concavity is turned towards the focus; its use is to collect for the mirror the greatest quantity of rays from the luminous source, and thus to augment the amplitude of the lighted space.

The beam which issues from the Mangin projector when the lamp is at the focus of the lens is perfectly limited by a circumference almost with-

out penumbra, and only has the divergence due to the dimension of the luminous source, that is to say, about $2\frac{1}{2}^{\circ}$; the light is uniformly distributed over all of its surface. By a simple change of focus, effected by an ordinary screw, this apparatus can light at will a considerable space, or all its intensity can be concentrated upon a single point. This property renders it eminently useful for certain military operations.

Messrs. Sautter and Lemonnier have already constructed a great number of photo-electric apparatus, for the army and navy, and, thanks to their ability, they have combined the different parts of the apparatus so as to assure perfect working.

Among the different installations made by them we will mention that for lighting the channel of the Caraque at Toulon. This channel is 1,800 meters wide. It is defended by twelve torpedoes, whose position is noted by twelve red buoys. The problem was to find at any moment a vessel under full steam, leaving Toulon and attempting to cross the channel at different places. The experiment was most conclusive. Scarcely had the vessel cleared the cape which closes the entrance of the harbor when it was perceived at a distance of more than 3,000 meters, and from this moment it could be followed, abandoned, and found again with the greatest facility.

This first trial being finished, it was desired to take account of the number of buoys visible at the same time. For this the luminous beam was projected on the foot of the fortification, and the line of separation of the land and water was clearly seen; then, elevating the beam little by little, the first, second, third, and fourth buoys appeared in succession; at this moment it was remarked that the beam could be raised sufficiently to see the twelfth buoy, 2,600 meters distant, without losing sight of any of the previous ones, although the latter did not receive the direct light; they were illuminated by the light reflected from the particles of water in the atmosphere. In consequence of the intensity of the luminous source and the exactitude given to the rays by the Mangin projector, the power of the beam was such that bodies placed outside its action and 10 meters below it were clearly visible.

A third experiment was then made. The diverging door was placed in front of the luminous beam, thus spreading it, and allowing to be seen on the other side of the channel, at a distance of 3,000 to 3,500 meters, a field more than 200 meters long, sufficiently illuminated to render easy all the operations of artillery.

Finally, it was desired to find out the maximum range that could be obtained. The diverging door was taken off and the concentrated beam was directed upon the heights which overlook Toulon. The observer, supplied with good opera-glasses and placed near the optical apparatus, could readily distinguish the barracks of Mont Faron, 9,500 meters distant and at an altitude of 500 meters.

The conclusions were unanimous. It was certain that the entire apparatus constituted a certain protection against torpedo boats which might attempt to cross the channel. These boats would be discovered in time to be fired upon by the fort, and officers placed at special posts could cause the explosion of the sunken torpedoes at the precise instant when the enemy's boats arrived within their radius of action. These experiments were made during a dark night. A light mist prevented the atmosphere from being absolutely clear.

The efficacy of the Gramme and Mangin apparatus was also recognized in the experiments made for the illumination of the north channel of the harbor of Cherbourg. Several boats were to cross this channel and to be recognized from the spot where the photo-electric apparatus was placed.

The greater number were easily recognized; then the beam of light was directed continuously upon one of them. When the captain of this boat arrived near the observers he expostulated with them; the electric light had prevented him from steering, and he had several times nearly collided with other craft.

During the Turko-Russian war, the coasts of the Black Sea were protected by similar apparatus, which were in use every night, notably at the port of Odessa.

For war signals, M. Gramme has devised a machine of very small size, which can be worked by hand. This machine, driven by four men, produces a light of about 50 carcels. It has flat electro-magnets, is mounted on a cart, and has two cranks acting on a double set of gear-wheels. Its construction is simple, and it is well adapted to its purpose.

There are now being made for different governments numerous apparatus for the projection of electric light, some portable, others worked by fixed boilers and coupled with their motors. One of the most successful engines is that arranged by Mr. Brotherhood, of London, with a three-cylinder engine, adapted especially for this work. The generator of electricity (system Gramme) is made at the workshops of Messrs. Santter & Lemonnier.

Messrs. Santter, Lemonnier & Co. had a complete exhibit of the various apparatus used for supplying electric light for military purposes, commencing with the engine used for driving the dynamo and ending with the projector for directing the light.

There are three purposes for which the electric light may be used in time of war—

First. To render visible during the night, at distances varying from 1,000 to 8,000 yards, such objects as houses, troops, earth-works, ships, boats, coasts, &c.

Second. To establish telegraphic communication between two points, either directly between the two points or by means of reflection from an

A special arrangement allows a slow movement, by means of a tangent screw, so as to bring the beam exactly in a direction determined beforehand.

The projector can be furnished with a door, with divergent lenses, which can be quickly removed. This allows the horizon to be explored for a great distance, and, when a doubtful object has been discovered, the diverging door can be removed, when the beam will illuminate the object with its full intensity, and, no matter how rapid may be its movement, it can be followed and illuminated. The apparatus can also be arranged for making signals, by sending flashes of longer or shorter duration.

The movable parts are supported on a cast-iron pedestal, which may be placed on a bridge of a vessel, in a casemate of a fort, or on a movable cart, as in the figure below.

FIG. 73.—Lenticular projector, mounted on a cart for the use of artillery.

This projector is provided with a horizontal and a vertical graduated circle and with electric lamps, either automatic or manipulated by hand. In the box at the rear is rolled the conducting cable.

With a four column, Gramme machine, size C, an observer at the side of the apparatus can distinguish objects 4,000 to 4,500 yards distant.

The French navy has placed on board the *Richelieu* and the *Suffren* some very powerful Gramme machines, driven directly by a Brotherhood engine and sending the light by means of these lenticular projectors.

The new engine of attack, the torpedo, carried or towed, places the heaviest iron-clads at the mercy of a swift torpedo-boat. Experience has

FIG. 74. — Projectors for ships' boats.

shown that however vigilant may be the watch on board a large vessel, a night attack by a torpedo-boat is often successful. The swift boat, running at 15 to 18 knots, arrives at its destination before its presence is suspected. It is very different if the object of attack can explore the horizon in every direction for a distance of 2 or 3 miles. The enemy will be seen some ten minutes before he can reach the vessel, which will give time for defense, even if the attack be not prevented, by the simple fact of its being discovered.

When the projector is placed on a vessel, the electric generator and its motor can be installed in the engine-room or elsewhere. The steam may be taken from the boilers of the main engine, but it is better to use a special high-pressure boiler for this purpose. The light can then be available while at anchor, without using the main boilers.

The location given to the lenticular projector has varied greatly. At first placed on the captain's bridge on the *Livadia*, it was afterwards preferred to place the base on a fixed post in the bow, and to mount the optical apparatus upon it when the light was needed. On board the iron-clad frigate *Namancia*, of the Spanish navy, a platform was built in the bow, and it is on this platform that the projector is placed and on which stands the officer who manœvers it. This latter arrangement seems the best; it permits the observer to be placed below the zone of the beam and not to be troubled by it; but it is only possible when the bow does not carry a bowsprit.

FIG. 75.—Gramme machine—hand power.

On the *Temeraire*, of the English royal navy, two projectors are placed, one on the port, the other on the starboard side.

The electric light is also employed on steam launches, used as vedettes, and furnished with an apparatus of projection, capable of either raising

the horizon for a distance of 1,500 meters or of corresponding by luminous signals with the ship to which they belong. The small space and little power at disposition on these boats, exact apparatus very light—not cumbersome—and in consequence much less powerful than those above mentioned.

The projector is no longer lenticular (Fig. 74), but a simple, silvered, parabolic reflector, mounted on the lamp; it is movable by hand around

FIG. 76.—The Mangin projector.

a horizontal axis, and the whole apparatus, inclosed in a very light box, can turn on a vertical axis. It can be quickly placed in the bow of the launch; the operator can then direct the rays in every direction.

The Gramme machine is so placed as to be driven either by motor or by four men working on a double crank. Whichever arrangement is adopted, the apparatus is not larger than the fourth of a cubic meter and does not weigh more than 250 kilograms. (See Fig. 75.)

The electric current is brought from the machine to the lamp by a cable with two copper conductors, perfectly pliable and sufficiently well insulated to allow them to be placed outside the boat and to be wet by the sea, in order not to interfere with the movements of those on board.

As a most successful substitute for the lenticular projector Colonel Mangin has devised the one known under his name. As lenticular projectors are costly, and in some degree absorb the light, parabolic reflectors are preferable, but the form is difficult to obtain with precision. The spherical form is the easiest to make, but the spherical aberration interferes with

FIG. 77.—The Mangin projector—side view.

its use when the light is projected to a distance. Colonel Mangin has ingeniously corrected this defect; he uses a glass mirror, the reflecting, spherical surface of which is on the interior, thus the ray traverses twice the thickness of the mirror before taking its final direction. Now, these two surfaces are not parallel, the interior surface being a sphere which has

a different radius from the other. The different thicknesses which the various rays have to traverse, according to the angle which they make with the axis, so modify them as to bring them rigorously parallel if the radii of the two surfaces of the mirror are in proper proportion.

It will be noticed that the carbons are inclined. This is because when a continuous current is used the maximum intensity of the light is not in a plane perpendicular to the line of the carbons, but in one about 30° below.

A small mirror is placed in front of the carbons to throw the light on the reflector. Other details of the apparatus are very similar to those of the lenticular projector. Smaller sizes are likewise made for the use of ships' boats.

The figure below shows one of these projectors placed on a wagon; the drum is mounted on a stand, whereby a motion in altitude and azimuth can be obtained.

FIG. 78. —Mangin projector, for use with artillery.

These projectors are necessarily costly. Experiments have been made in England to protect them from the enemy's fire, behind and below the parapets, and to reflect the light from them in the desired direction, by means of plane mirrors.

The following table will show how well this apparatus will work :

Table showing the divergencies and diameters of the images obtained, at various distances, with various Mangin projectors.

Size of projector, &c.	Distance of light from mirror.	Divergencies.	Diameter of illuminated circles in meters at—						
			1,000m.	2,000m.	3,000m.	4,000m.	5,000m.	6,000m.	7,000m.
	Meters.	Degrees.							
Projector, 30 ^m in diameter									
Light, 6 ^{mm} in diameter...	0.160	2	30	60					
Gramme M	0.170	9	180						
Projector, 40 ^m in diameter									
Light, 10 ^{mm} in diameter..	0.240	2½	45	90	135				
Gramme A	0.250	6½	60	120	180				
Projector, 60 ^m in diameter	0.260	11½	100	200	300				
Light, 15 ^{mm} in diameter..	0.430	2	30	60	90	120	150		
Gramme D	0.440	4	78	156	234	312			
	0.450	6	118	236	354				
	0.460	11	198	396					
Projector, 90 ^m in diameter									
Light, 15 ^{mm} in diameter..	0.760	2	15	30	45	60	75	90	105
Gramme D	0.770	3	25	50	75	100	125	150	175
	0.780	4	45	90	135	180	225	250	
	0.790	5	60	120	180	240	300		
	0.800	7	115	230	345	460			

Figure 79 shows a portable electric-light apparatus for the French military service. It consists of a portable engine fitted with a Gramme generator and lamp, a Mangin protector, and a length of conductor placed on a reel. The Gramme machine is driven directly by a Brotherhood three-cylinder engine. This type has recently been adopted by the French Government, and is especially intended for use in fortifications and other defenses.

Figure 80 illustrates a somewhat similar arrangement, constructed for the use of the French army, the engine in this case being self-propelling, and may be used for the transport of guns or stores, while, at the same time, it carries an electric light apparatus. As before, a Brotherhood three-cylinder engine and a Gramme machine are used.

NOTE.—Further details of this and other similar apparatus will be found in Ordnance Notes No. 240, February 5, 1883, reprinted from Engineering.

FIG. 79 — Portable electric light apparatus for French military service.

FIG. 20.—Self-propelling engine with dynamo.

ELECTRO MOTORS

LIST OF ELECTRO MOTORS.

The Trouvé motor.	The Deprez motor.
The double induction motor of Mr. Griscom.	Experimental form Duprez motor.
The Elias electromotor.	The Cloris Bandet electro motor.
The Bürgin "spherical" motor.	The Jablochkoff electro motor.

ELECTROMOTORS.

INTRODUCTION.

Before describing the electromotors at the Exhibition, it will be interesting to know to what degree of perfection this branch of electrical science had been carried to within a few years before the Exhibition. I therefore translate the following from the "*Exposé des applications de l'électricité*," by the Comte du Moncel, published in 1878. He explains the difficulties to be overcome and tells what success had been obtained up to that time.

When we come to the motors of the Exhibition the reader can judge for himself of the progress made in the intervening years.

[Translation.]

Attempts have been made for the past thirty years to employ the attractive effect of electro-magnets or the dynamic effects of currents as a motive force. This question to-day still occupies many heads, and, considering the ardor displayed to solve this problem, one would say that it was no less a question than the discovery of the philosopher's stone in mechanics. Without doubt the creation of a non-explosive motor, which would need no one to attend it, which could be situated wherever it would be most convenient without needing a special building, which could be made to act with more or less force according to the work required from it, finally, whose size would not be cumbersome, would be very important, especially for the minor industries, but we should not have too many illusions on this point. It is not in mechanical combinations or perfections that the solution of the problem should be sought, but rather in the removal of the obstacles which are inherent to the electro-motive force itself. Now, these obstacles are so complex, and the effects which are the consequence of them are so contradictory, that it can almost be predicted that those motors which are most successful when of small size are precisely those which give the worst results when of large size, should they still give any, which does not always happen. A great number of persons—as many in France as in Germany, England, and America—have

spent much money for the construction of these motors, and have arrived at this conclusion: that the electromotive force is only susceptible of application in very narrow limits, which cannot exceed those of clock-work.

All the effects of the electric fluid capable of impressing on a body a direction, or of developing a force of attraction or repulsion, can be combined mechanically, so as to form an electromotor. Thus the effects of electric currents upon each other, the action of currents upon magnets, and reciprocally the action of magnets upon currents, the action of temporary magnets upon magnetic bodies, non-magnetized, can, if one augments sufficiently the electric force and the size of the pieces subject to its action, give rise to electro-dynamic motors. One can readily conceive that, possessing by means of electricity, a force which can be destroyed at a given moment, since it is only a question of interrupting the current, a very simple mechanism would suffice to translate the direct impulse to a continuous circular movement.

If the electro-motive force was like steam, capable of increasing with the elements which give it birth, if the dynamic action could act within a certain distance with the same intensity, if the electric fluid did not react by induction so as to exercise a contrary effect to that intended to be produced, if the current were transmitted in all its strength during a very short period of time, if, finally, the cessation of magnetic action corresponded exactly to the interruption of the current, the problems of electromotors would have been solved long ago, for never have more ingenious combinations been devised. But it is very far from being so, and besides these obstacles others are added which are part of the nature of bodies themselves: first, their lack of rigidity, which is the natural consequence of their elasticity; secondly, the oxidation of the interrupter by the electric spark, which deteriorates this mechanism and hinders the perfect continuity of the metallic communications; finally the same stability of the effect at a distance for a powerful magnet as for a feeble one.

All these obstacles which interfere with the action of electromotors of large size do not exist for small ones, for the elements of electro-magnetic action remain nearly the same; now, that which might be a great result for a small motor would be a very feeble one for a large motor; this lack of rigidity which destroys the benefit of the effects at a small distance is not felt for feeble forces and short lever arms; finally the spark of a feeble current in no way injures the metallic communications. This is why the electromotors of a small model have always succeeded, while large ones have always deceived the hopes of their inventors.

The conclusion of all this is that one should for a long time, if not forever, be on guard against the pompous announcements of certain constructors and of certain periodicals, who affirm that electromotors can be

established having the force of several horses. What is certain is that *up to the present time no motor has equalled one horse-power*, and those who treat the problem as solved recall to us the fable of the hunter who sold the bear's skin before he had killed the bear.

Although the causes which we have just mentioned re-act in a troublesome manner on the development of the electro-motive force, they are not all, however, insurmountable, for it has been found possible to diminish the contrary effects of induction currents, the deteriorating action of the electric spark, the injurious action of the remaining magnetism. On the other side, attempts have been made to avoid the difficulty of the rapid diminution of the magnetic force with distance by reaction at the point of contact, and by utilizing the directing forces of the magnetized organs. In spite of all these improvements the problem is not yet solved, and until now the only results which have been obtained have been confined to driving sewing-machines, mechanical pianos, small turning lathes, counters of large size, machines for cutting and engraving, experimental apparatus, machines for covering copper wire with silk and cotton, &c.

ELECTROMOTORS.

One of the most interesting applications of electricity at the Exhibition was that of its use as a motive power. During the past few years the labors both of physicists and inventors have mainly been in the line of electric lighting; but, with a few exceptions, the whole field of "force produced by electricity" has remained untouched.

Besides coal, the great source of power, there exist on the surface of the globe certain natural forces of an absolute permanence which are inexhaustible and which can yield energy to an enormous degree, but the problem of utilizing them has yet to be solved.

The chief of these are water-courses and water-falls; and the transmission of power to considerable distances has also been accomplished by means of cables. But the direct application of water-power must always be local, and hitherto has been limited to the site of supply. Electricity, however, allows of the transmission and distribution at a distance of power produced by the fall of water, by the force of the wind, by steam-engines, or by other means:

At the Exhibition is shown a series of electric machines driven by various motors which communicate to them a rapid rotation by means of belting. This movement is transformed into electricity; but the same machines, if there was furnished to them from some other source the electricity which they themselves produce by rapid revolution, would themselves revolve and transmit to the shafts and belting connected with them

a power that could be utilized. This is the interesting phenomenon known as the reversibility of magnets and dynamo-electric machines.

The transmission of force by means of two dynamo-electric machines coupled together is effected with a loss of about 50 per cent. between the power applied and that delivered. But great as this waste is, it is not too extravagant to permit of application in certain cases, and sometimes would be more economical than a number of small independent steam motors as compared to the power produced by one large central motor, less costly than a number and consuming less fuel. And the economy is of course greater when the source of power is natural and costs nothing.

Electricity thus furnishes a means at once simple and convenient, of distributing the power developed by a fall of water over a considerable radius by dynamo machines located at the source of power and driven by turbines, with a system of insulated conductors transmitting the current to a series of distributing machines.

Practically, however, the problem is a complicated one and has not yet been satisfactorily and entirely solved, though important steps have been taken in this direction.

Heretofore, in searching for a motive power for movable torpedoes or submarine torpedo-boats, the means adopted have been virtually confined to compressed air or carbonic-acid gas, which, by its expansion, would actuate the machinery for propelling the boat. When this store of gas was contained in the boat the distance to which the latter could go was naturally limited by the amount of air or gas it could contain. When this was exhausted the boat came to rest. When the air was furnished from shore the motion of the boat was hampered by the tube, which the boat would either have to carry or tow. Could, however, the boat be furnished with a small, light, and sufficiently powerful electromotor it could be supplied with electricity from shore and its range greatly increased, as the conducting wire could be made smaller and lighter than any tube.

None of the small motors exhibited and about to be described would answer the purpose above mentioned, but they may furnish hints by means of which better and more powerful motors may yet be made, suitable for propelling one of the most powerful military engines yet invented, and especially adapted for the protection of our coasts, whose defense, in the absence of suitable fortifications and of a navy, calls for any appliance which the ingenuity of man can devise.

The Exhibition contains several applications of the transmission to a distance of currents devoted to the production of energy. In place of using two machines, the one productive and the other receptive of the current, connected in circuit, the receptive machine may be supplied by a battery, or by an accumulator like the Faure or Planté batteries.

THE TROUVÉ MOTOR.

The system adopted by M. Trouvé consists in the production of the current by means of a secondary Planté battery or a Trouvé bichromate battery, which will be found under the head of batteries.

The Trouvé motor was explained by the inventor for the first time before the Academy of Science of Paris, France, on the 28th of June, 1880.

The following is a summary of his remarks:

If the dynamic diagram of a Siemens coil, making a complete revolution between the magnetic poles reacting on it, is traced out, it will be seen that the work is almost *nil* during two very sensible portions of the

FIG. 81.—The Trouvé electromotor.

revolution. These correspond to the time during which the cylindrical poles of the coil, having arrived at the poles of the magnet, pass before them.

During these two portions of the revolutions, which are each about 30° , the magnetic surfaces which react, one on the other, remain at the same distance; the coil is not therefore induced to revolve, and a loss of work takes place.

In the Trouvé motor these idle periods are removed, and the useful ef-

fect of the apparatus is increased by modifying the coil; the polar faces, instead of being parts of a cylinder, the axis of which coincides with that of the whole system, are made spiral, so that in turning they approach gradually to the surface of the magnet, up to the moment when the rear edge passes the pole of the magnet. The action of repulsion then commences and the dead points are practically suppressed.

Fig. 81 represents the motor as actually made; A A are the poles of the fixed electro-magnet; B is the iron core of the modified Siemens coil; C is the coil of the electro-magnet; I is the axis of the coil; F H are the poles of the actuating battery; D is a copper frame, and E an independent cast-iron frame.

FIG. 82.

FIG. 83.

FIG. 84.

The vertical section (Fig. 82) shows the spiral form of the coil. The fixed electro-magnet is marked *a a b* and the movable coil *c c ff*. In one of M. Tronvé's arrangements the magnet tube is oval and the coil circular; in another the magnet is circular and the coil is spiral, as shown in Figs. 83 and 84.

M. Trouvé has obtained remarkable results compared with the weight of the apparatus. A tricycle weighing 120 pounds was driven by means of a motor and six Planté secondary batteries. The total weight of vehicle, rider, batteries, and motor was 350 pounds. The motor, weighing 11 pounds, propelled the vehicle at the rate of $7\frac{1}{2}$ miles an hour.

M. Trouvé has also applied the motor to a small boat shown at work at the Exhibition, on the central basin where the great light-house was reared.

FIG. 85.

Fig. 85 shows the general arrangement of the boat; the batteries are placed amidships and the motor is mounted on the rudder. The latter is

shown more clearly in Fig. 86, which explains the connection between the screw and the rudder. In large boats the motor would be placed direct on the screw shaft. On the lake in the Bois de Boulogne the speed attained

FIG. 86.

was 10 feet per second with a four-bladed screw. The boat was 18 feet long and 4 feet wide. The weights were as follows:

	Pounds.
Weight of boat	176.
Weight of batteries	52.8
Weight of motor.....	11.0
Weight of three passengers.....	528.0
Total	767.8

The motor has also been applied to the propulsion of toy boats and to a model balloon devised by M. Tissandier.

These applications to both boat and balloon, though of not much prac-

tical value, are of interest as illustrations of electricity as a prime mover. The motor may and probably will find many applications where very small powers are required.

THE DOUBLE INDUCTION MOTOR.

The most successful small motor at the Exhibition was one bearing the above title, the invention of Mr. W. W. Griscom, of Philadelphia ; taking into consideration its size, weight, cost, and efficiency it surpassed every other small motor shown. The inventor thus described it :

The machine consists simply of a small Siemens armature, revolving in a fixed ring of malleable cast-iron, about $2\frac{1}{4}$ inches long and 3 inches in diameter. On opposite sides of this ring poles are formed, as shown in the figure, about 1 inch wide, and extended at each end to afford a means of attaching the end plates of the machine, which

FIG. 87.—The double induction motor.

carry the bearings, binding-screws, &c. With the exception of the poles the ring is covered with two coils of coarse wire, both coils being connected with each other, and also with the battery that ordinarily serves as the source of power. The battery current is also led to the revolving armature by means of two pairs of small rollers mounted at the ends of light springs attached to one of the circular end plates, the direction of the current being reversed at each revolution of the armature.

(NOTE.—These rollers have since been suppressed, as it was found that they defaced the armature by continual pounding while passing from one-

half of the armature to the other over the insulating material between the two halves. Their place has been supplied by copper springs, which can readily be replaced when worn out.)

The pole pieces of the armature are curved so as to be concentric with the inclosing rings, and of such dimensions that they are in very close proximity to the inner surface of the coils around the ring. As the revolving armature constitutes an electro-magnet, induced currents are developed, which, on account of the arrangement of the commutator, are always of the same nature for one-half of the ring, and of the opposite nature for the other side of the ring; that is to say, each pole of the revolving armature is alternately north and south during each revolution, being changed by the action of the commutator, as the armature passes the opposite poles of the inclosing ring. The coils around the fixed ring are wound in opposite directions, so that the currents induced by the opposite poles of the armature at the same time are of the same nature, and instead of neutralizing each other contribute to the efficiency and power of the motor, while their direction is always the same as that from the battery which electro-magnetizes the fixed armature. From this description it will be seen that the principle of the machine is to utilize the induction currents from the revolving armature and to add them as supplementary and useful currents to that passing from the battery to the coil on the ring.

This utilization of the induced current, which in other motors has been a fatal disadvantage, is a feature which greatly increases the facility of working, and enables us, with very light weight and in small space, to have a really powerful engine.

Figure 88 will assist in understanding the above explanation. The inventor's claim that the induced currents assist in the working of

FIG. 88.

the machine has been contested. Without going into the merits of the case, I will simply say that it does not seem possible that the induced

currents can be added to the current proceeding from the battery. If this were so, we would have more current passing through the coils of the motor than the battery furnishes, which seems absurd.

FIG. 89.—Model showing double induction.

However, to present the inventor's claim more clearly, I will add a description of a "model motor," specially constructed, to show the effects of double induction. Figures 89 and 90 present a general view of the apparatus and a diagram.

FIG. 90.—Diagram showing connections, &c.

The motor consists of an ordinary Siemens armature, A, revolving between the ends of a soft iron horseshoe, I. The latter is coiled with wire,

W, and the ends, EE', may be left free or they may be connected together, forming a closed circuit round the horseshoe. The commutator, C, is of the ordinary construction, and the rubbers, BB, are made in the form of the Gramme brushes. These may be adjusted at any point on the commutator, being movable on a center, as is shown in the general view of the apparatus. This model motor will revolve in either direction by shifting the brushes more to the left or to the right. If a battery be connected to the brushes, as shown in the diagram, and the armature magnetized, attraction immediately ensues between the poles and the ends of the soft iron horseshoe, the ends, EE', of the coil, W, being left quite free, and the armature begins to revolve rapidly. Now, if the ends, EE', be joined together, forming a closed circuit round the horseshoe, the armature increases its pace in a great degree.

The inventor holds that this model, although different in construction, is identical in principle to the present form of the motor, and that the extra speed given to the armature on closing the circuit of the coil W, proves that the induced current adds to the power of the battery current.

My view is that the induced currents are in a great measure neutralized and thus an obstacle is removed, not an additional power added. The motor may be driven by a battery, or several motors by a dynamo-electro machine, or by accumulators. One bichromate battery of six cells is sufficient to drive such a motor as has been described at a speed of five hundred revolutions per minute, the power developed being sufficient to work a small lathe or a sewing-machine, at a very rapid rate. The intensity of the current, and therefore the speed of the motor can be regulated by immersing the couples of the battery more or less deeply in the solution, which is done by means of a pedal placed conveniently to the foot of the operator. The battery is described under the head of "Batteries," page 16. The box containing the battery can be used as a seat for the operator.

THE ELIAS ELECTROMOTOR.

A model of this motor was contributed by the École Polytechnique of Delft, and was exhibited in the Dutch section; it is interesting, as it may be considered in some sense a prototype of the Gramme machine, although it has radical differences, and was, moreover, constructed for an entirely different purpose, for it is in fact an electromotor, while the Gramme machine is an electric generator. This apparent resemblance makes it necessary to point out the differences between it and the Gramme machine. Its very early date, 1842, also gives it an exceptional interest.

The apparatus consists of an exterior ring of iron, about 14 inches in diameter, and 1.5 inches wide. It is divided into six equal sections by six small blocks which project from the inner face of the ring, and which act as so many magnetic poles. On each section is rolled a coil of one thick-

ness only of insulated copper wire, the wire being .04 inch in diameter, but when insulated has a thickness of .2 inch. The wire forms twenty-nine turns in each section, and the direction of winding changes at each passage in front of a pole piece.

The ends of the wire coinciding with the horizontal diameter of the ring are stripped of the gutta percha and are connected to copper wires which are twisted around two vertical copper rods, whose lower ends enter two small cavities in the base of the apparatus. The circuit is thus continuous with two ends at opposite points of the same diameter. The ring is about 1.1 inch thick and is fixed to two wooden columns, B B, by two blocks of copper.

FIG. 91.—The Elias electromotor.

It will be seen from the mode of coiling the wire on this ring that if a battery be connected by means of the copper rods the current will create six consecutive poles on the various projecting blocks.

The inner ring E is about 11 inches in outside diameter, and is also provided with a series of six projecting pieces which pass very close to those on the exterior ring; the space between them is .40 inch. The inner ring is movable and is supported by three wooden arms, F, fixed to a base, G, which is traversed by a spindle supported in bearings by the columns A and C. A coil is wound round this ring in exactly the same way as that on the outer ring, the wire and insulation being of the same thickness. The ends of the wire are also bared at points of the diameter opposite each other and the coil connected in pairs so as to form a continuous circuit. At the two points of junction they are connected with a hexagonal commutator placed on the central spindle; one end corresponding to the sides 1, 3 and 5, and the other to the sides 2, 4, and 6. Two copper rods, J, fixed on the base to two plates of copper furnished with binding screws are widened and flattened on their upper ends to rest against opposite parallel sides of the hexagon. If a battery is put in circuit by means of the binding screws, the current in the interior ring will determine six consecutive poles, the names of which will change successively with the sides of

the hexagon. Consequently, if at first the pole pieces opposite each other are magnetized with the same polarity they will repel each other, and the inner ring will be set in motion; the effect will be increased on account of the attraction of the next pole of the outer ring. At the moment when the pole piece thus attracted comes into the field of opposite polarity, the commutator will change its magnetization, while that of the pole piece on the fixed ring will always remain the same; the same phenomenon will be produced, and the inner ring will continue its movement in the same direction. To the action of the magnetic poles has to be added the reciprocal action of the coils around the rings.

From this explanation the differences between the Gramme machine and the Elias motor will be understood. Elias did not contemplate the production of a current; he used two distinct sources of electricity to set the inner ring in motion, and did not imagine it was possible by suppressing one of the inducing currents and rotating the ring rapidly to obtain a current.

THE BÜRGIN "SPHERICAL" MOTOR.

This motor was exhibited in the British section, and is curious from its mode of action. It consists of two hemispheres fastened to each other and upon which are wound insulated wires in the direction of parallels of latitude. In the interior of this spherical box, which is firmly supported on a base, is placed a kind of spherical electro-magnet mounted on axis of rotation, and on which the insulated wire is wound, so as to form a base, the axis of rotation being parallel to the plane of winding. When

Spherical box.

Spherical electro-magnet.

FIG. 92.

the electro-magnet is vertical both sets of windings will be in parallel planes, but when the electro-magnet is horizontal these planes will be perpendicular to each other, and if the electric current flows simultaneously through both sets the electro-magnet will tend to take that position in which the planes of the windings are parallel, but if at this moment the current is reversed in either set of windings a moment of repulsion will

succeed that of attraction until the magnet has made a half revolution, then a new reversal of the current will continue the motion.

To obtain this result, that is, a continuous movement of rotation of the motor, it is only necessary to place a commutator and a collector of the current on the axis, and if a pulley is fixed on the end of the same axis the motor can transmit its motion like any other electromotor, without, at first glance, it being perceived how motive power can be produced from this box surrounded with wire.

THE DEPREZ MOTOR.

M. Deprez, in his search for a small electromotor, first modified the Ladd-Siemens machine to adapt it for this purpose, it having been previously only used as a generator.

FIG. 93.—Ladd-Siemens machine, used as a motor.

The Deprez motor was the only one exhibited in which the magnetic field was obtained by permanent steel magnets.

The inventor states that after making experiments with the Ladd-Siemens machine he was led to adopt his present style of motor. The following is a translation of his own words :

Theoretical considerations, which it is useless to recall, have shown me that this kind of motor would give better results (*rendement*) if the magnetic field were made by a permanent magnet in place of an electric magnet, whether it was used as a motor or a generator. I then had constructed the model which is known under my name and in which the utilization of the magnet is carried to its last limits.

Very numerous experiments made by M. d'Arsonval showed that my theory was correct, and that the motor with permanent magnets gave better results than the modified Ladd machine. I will add that as a generator of small size it is very supe-

rior to the latter. These motives determined me to adopt definitely the model with permanent magnets.

Among the many attempts which I have made to reduce still more the weight and size of my motor, there is one which I believe to be of sufficient interest to mention here, although it has scarcely more than a historic interest, and whose results were inferior to my first model. It is shown in the figure below. It consists of a fixed Sie-

FIG. 94.—Experimental form of Deprez motor.

men's armature, C, and of a circular electro-magnet, B B, whose poles are at I L. The axis of the armature serves as a spindle for the electro-magnet, which is mounted so as to turn freely upon it. The brushes D D and the commutators A A serve to produce all the combinations possible in these two pieces.

By giving the armature C different inclinations, which it will keep on account of the friction against the supports upon which it is mounted, the effects will be identical to those obtained by changing the contacts of the brushes; and, besides, the current can be changed twice in each revolution, either in the armature C, the electro-magnet keeping the same polarity, or in the latter, the Siemens armature then acting as a permanent magnet. This latter arrangement, it must be understood, was only an experiment to show the error in which many had fallen who before me had made use of electromotors in which electro-magnets of considerable mass were submitted to rapid changes of magnetism.

The reader will see the close resemblance between this model and that of Mr. Griscom showing double induction; the principal difference being that in the latter it is the Siemens armature which revolves. M. Deprez claims that he constructed it in 1880, and afterwards abandoned it for his present model. This is composed of a horseshoe magnet, formed of eight superposed plates. Between the poles of this magnet is placed a Siemens armature, the axis of which is parallel to the arms of the magnet. The armature is a cylinder of very soft iron, having two longitudinal grooves in which is wound the wire, each of the ends of which is connected with one of the semicircles of brass which form the commutator (seen to the right of Fig. 95).

The current reaches the commutator through brushes made of fine brass wire. The current which traverses the wire of the bobbin B has the effect of forming in the latter two poles of great length, which change character the instant they pass before the poles of the magnet. The armature therefore revolves in a direction depending on the direction of the current traversing it.

FIG. 95.—The Marcel-Deprez electric motor. (One-quarter actual size.)

The brushes are mounted on a support capable of turning around the axis of the armature. This arrangement permits the speed of the motor to be changed without altering its results.

The weight of the above model does not exceed 9 pounds. The normal velocity of the armature is three thousand revolutions per minute; this corresponds to one hundred reversals of the current per second in the armature. A speed governor has been added to the machine; this consists of a spring, one end of which is attached to one end of the armature wire; the other end rests on the commutator; when the rotation becomes too rapid the spring opens from the centrifugal force, and contact is broken and remains broken until the speed again becomes normal, when contact is again renewed; this maintains the variation of within $\frac{1}{60}$ of the normal rate.

The longitudinal arrangement of the armature in place of the transverse utilizes the whole power of the magnet and renders a motor of equal power much lighter.

With the small motor just described connected with four Ruhmkorf elements in tension the work developed was 2.42 foot-pounds.

This machine is reversible, that is to say, by turning the crank fixed to the pulley it acts as a continuous current machine, whose electro-motive power reaches three Bunsen elements.

This motor was exhibited in connection with M. Baudet's batteries, and was worked by them during the Exhibition. The principal feature of this motor is the revolving armature, which may be straight, like the Siemens armature, or circular, like the Gramme ring.

The first arrangement consists, like the Siemens armature, of two longitudinal poles parallel to the axis; but instead of making the enlarged poles of a flat magnetic core, surrounded by the magnetizing helix, these poles consist of two armatures placed on the poles of a certain number of little electro-magnets, arranged in order, and so wound that one-half of the armature forms the north and the other half the south poles, as seen in Fig. 96.

FIG. 96.

All these little electro-magnets are united in quantity for each series, which allows the number of windings to be increased on each, while diminishing the total resistance. Finally, to avoid dead points, it is divided in two parts on the axis of rotation.

FIG. 97.

FIG. 98.

Figs. 97 and 98 show the motor in the most simple conditions, the fixed magnet being composed of two bars with coils at their centers, and the movable armatures, of the kind just described, are placed between the four poles of these bars. The total weight of this apparatus is about 7.7 pounds.

FIG. 99.

FIG. 100.

When the machine is to be employed as a generator, and in order that it should have larger dimensions than the preceding, M. Baudet gives the revolving armature another shape, shown in Fig. 99. On the little magnets are placed flat iron rings, one-half of one ring being of north the other

half of south polarity, the opposite plate, of course, being polarized in a contrary sense. This armature revolves between opposite poles of the two electro-magnets. The induction is caused by the continual displacement of the poles on the two circular armatures, which thus forms two circular magnets revolving in front of the fixed poles of the electro-magnet, the same as in most other machines.

The exterior form resembles the Gramme machine. The advantages claimed are ease of construction and facility for making repairs, owing to the manner in which the armature is wound.

THE JABLOCHKOFF ELECTROMOTOR.

FIG. 101.

This motor was not shown at the Exhibition, but as it makes an interesting addition to the subject, and is quite peculiar in form, it is thought worth while to describe it. Its working depends on the attraction and repulsion of a permanent and moving electro-magnet, and of a fixed solenoid traversed by alternating and opposite currents. In this respect it resembles the spherical motor of M. Bürgin, of Fâle, and the Elias motor (both of which were exhibited), except that in

FIG. 101 a.

the Elias motor it is the fixed ring which is permanently magnetic and the movable electro-magnet which changes its polarity.

The Jablochkoff motor consists essentially of two coils, one fixed and set in a vertical plane, and the other movable and fixed in an inclined position on a horizontal axis; it is on account of this arrangement that the apparatus has been called the "ecliptic" motor. (See Fig. 101.)

The fixed vertical coil is not in a plane perpendicular to the axis of rotation, but makes a certain angle with this plane, determined by experiment and varying with the conditions of working. The fixed coil is wound on a copper frame, while the revolving coil has an iron core, which, under the effect of the current traversing it, is converted into an electro-magnet, the poles of which are formed by the two circular disks. On the axis is a commutator between which are placed four brushes. This commutator is combined in such a way that during rotation the movable coil is transversed by a current never changing its direction, and maintaining in the flat electro-magnet a permanent polarity, but at each half revolution the current is reversed in the fixed coil.

FIG. 101 b.

FIG. 101 c.

FIG. 104.

Referring to the diagrams, Fig. 101a shows a simple form of machine, such as has just been described. The bobbin A having checks, *a b*, of soft

iron, and wound with a coil of insulated wire, is fixed obliquely on the axis *O*, and revolves between the poles of the electro-magnets *N* and *S*. The obliquity of the coil is such that in each revolution it presents the edges of *a* and *b* alternately to the poles *N* and *S*, and alternating currents are set up in the coil *A*. Fig. 101 *b* shows a construction in which the coil *B*, fixed obliquely on the axis *O*, revolves within an oblique bobbin, *C*, which has an iron sheath, *F*, presenting interior polar edges towards the edges of *B*. The electric currents set up in the coil of *B* are collected and converted into currents of uniform direction by means of a commutator, *D*, of ordinary construction.

In the construction shown in Fig. 101 *c* the exterior bobbin *C* is of soft iron, constituting a solenoid.

As in the Elias machine, the commutator *D* may be applied, as shown in Fig. 101 *c*, to alternate the currents in the coil of *C*, those in the coil of *B* being constant in direction, collected in the usual way by rubbers bearing on rings at *O*. In this case the internal bobbin *B* need not be of soft iron.

When the machine is of large diameter the interior coil *A* may be merely a ring of iron fixed on a wheel of non-magnetic material, Fig. 101 *d*.

These machines may be used either as dynamo-electric machines or as electromotors. The efficiency of the machine is not known, but it has the advantages of simplicity, strength, and cheapness to recommend it.

EXPLODERS.

LIST OF EXPLODERS.

Siemens magneto-electric mine-exploder.
Siemens dynamo-electric mine-exploder,
for tension.

Siemens dynamo-electric mine-exploder,
for quantity.
The Deprez magneto-electric exploder.

EXPLODERS.

The advantages of using electricity for exploding mines, blasts, &c., are so numerous and well known that it is not necessary now to give reasons for its use.

Messrs. Siemens Brothers exhibit :

1. A MAGNETO-ELECTRIC MINE-EXPLODER, specially designed for blasting operations, in which only a small number of shots are fired. This apparatus consists of six powerful permanent magnets, between the poles of which there is a Siemens armature, to which motion is given by means

FIG. 102.

of a handle and toothed gearing. One complete revolution of the handle causes the armature to turn thirteen times, and at each turn two currents of opposite direction are induced in the wire coil, or a total of twenty-six currents for each revolution. It fires twelve Abel's fuses in single circuit simultaneously and with certainty. The working parts are inclosed in a teak-wood case; the handle can be taken off and placed inside the case. A larger size, with nine magnets, can fire simultaneously about seventeen Abel's fuses in single circuit.

2. SIEMENS DYNAMO-ELECTRIC MINE-EXPLODER consists of an *electro*-magnet and an ordinary Siemens armature, which, by the turning of the handle is made to revolve between the poles of the *electro*-magnet.

By the automatic action of the machine a very powerful electric current is produced and sent in the leading wire to the fuse. The fuse being practically either an interruption of the circuit or a great increase in its resistance by the interposition of a badly-conducting substance, the consequent action is that either an electric spark passes between the interrupted portions of the conductor, or the piece of bad conductor is highly heated, causing ignition of the explosive substance contained in the fuse.

Figure 103 shows the apparatus with its cover removed. A is the revolving armature, on the axle of which is a pinion driven by the wheel R, which is turned by the handle at the end of the machine; F F are the

FIG. 103.

electro-magnets; C is the commutator, by means of which the currents of alternate directions generated in the armature are caused to flow only in one direction through the coils E E of the electro-magnets. After every two revolutions of the wheel R, which is fastened on the same axle as the wheel R, a tooth of the lever D falls into a notch in the cam S, and causes the end of the lever to be forced by the spring beneath it into con-

tact with the screw *d*, thus breaking the short circuit hitherto existing in the instrument and causing the current to pass to line by the terminals *e e*, to which the line wire is attached.

These dynamo-machines are of two kinds, viz :

The dynamo-electric tension-exploder, and

The dynamo-electric quantity-exploder.

The former, which has just been described, has its coils, both of the armature and the electro-magnets, wound with fine wire to a total resistance of 2,000 to 2,500 Siemens's units in about 17,000 windings. Upon causing the armature to revolve, currents of high electro-motive force are generated, and an electrical spark passing between the separated conductors in the fuse, inflames the explosive priming. This apparatus fires simultaneously about 50 Abel's fuses in single circuit.

The *small tension-exploder* is of the same construction as the large one, but weighs about one-half; it is placed in a leather knapsack for transport. It will fire about 30 Abel's fuses in single circuit.

The *large quantity-exploder* is similar in construction to the tension-exploder, except that the cam *S* and short circuiting lever *D* are omitted. The electric current is, after a few turns of the handle, sent into the line wire by pressing down a firing key at the top of the instrument. The current then passes continuously into line until sufficiently powerful to heat the bridge wire in the fuse and cause ignition of the explosive priming. The coils are wound with wire of large diameter to a total resistance of 8 to 10 units in about 2,000 windings. Electric currents possessing great *heating power*, but of small *electro-motive force*, are generated by this machine.

The standard of efficiency of these machines is the fusing of a quarter of an inch of iridio-platinum wire of .0015-inch diameter, weighing .45 grain per yard, through a line resistance of 70 Siemens's units.

The *small quantity-exploder* is of the same construction as the large one, but its weight is about one-half; it is packed in a leather knapsack. It fuses a quarter of an inch .0015-inch iridio-platinum wire through a line resistance of 50 Siemens's units.

The subjoined table gives particulars concerning these exploders. The *tension-exploders* are best suited to mining purposes, where fuses have to be exploded *simultaneously* or through long circuits. The dynamo-exploders are the best for blasting. The tension-exploder is usually preferred in consequence of tension fuses being cheaper than platinum fuses. When, however, a system of mines has to remain a long time inoperative, and yet in a condition to be fired at a moment's notice, daily electrical tests must be taken, and this can only be done when platinum wire fuses are used.

Comparing electric exploders with frictional electrical machines and galvanic batteries, the dynamo electrical apparatus has the advantage of being more certain and safer than the former, and more portable and less trouble to keep in order than the latter.

TABLE.

Description of exploder.	Dimensions.		Weight.		Length of spark.	Average number of Abel's fuzes machines will fire.
	Inches.	Millimeters.	Pounds.	Kilograms.		
Magneto-electric tension-exploder with 6 magnets.	10×7×7	254×178×178	22	10	1430	12
Magneto-electric tension-exploder with 9 magnets.	10×8½×7	254×216×178	29	13	1380	17
Small dynamo-electric tension-exploder with knapsack.	12×11×6	305×280×152	35	16	1300 1000	30
Large dynamo-electric tension-exploder.	15×15×7	381×381×178	59	27	1200 1000	50
Small dynamo-electric quantity-exploder with knapsack.	12×11×6	305×280×152	39	18	Fuzes ¼" length of 0".0015 iridio-platinum wire through 50 units.	35 service detonators, No. 13.
Large dynamo-electric quantity-exploder.	15×15×7	381×381×178	71	32	Fuzes ¼" length of 0".0015 iridio-platinum wire through 70 units.	44 service detonators, No. 13.

DEPREZ MAGNETO-ELECTRIC EXPLODER.

This exploder, instead of using the current directly engendered on the armature of an electric magnet when its contact is suddenly broken with a permanent magnet, first passes the current thus produced in the conducting wire of a Ruhmkorff coil, and then uses the induction wire of the coil to produce the spark. This modification in the manner of using the apparatus requires others in its construction, and in the relative sizes of its various parts.

As the current which traverses the induction wire of the coil should be of considerable intensity, the wire of the armature should be large, and in addition the breaking of the current produced by the sudden separation of the electro- from the permanent magnet, should take place when this current (which starts from zero to return to zero in a very short interval of time) arrives at its maximum intensity.

To accomplish this last condition, M. Deprez designed a new circuit breaker for induction coils which it will be necessary to first describe. Circuit-breakers previously used had numerous defects, which very much reduced the useful effect of the coils to which they were applied for the following reasons:

When the inducing current has just been closed, it does not require instantly its full intensity, the increasing magnetization of the bundle of iron wires forming the core develops an electro-motive force opposite to

that of the battery, so that, during a time which depends on the power of the battery, on the resistance of the inducing circuit, on the number of windings surrounding the bundle of iron wires, and on the mass of the latter, the intensity of the current passes through a series of successive values. Finally, at the end of a very short but appreciable time, the intensity of the current reaches its definite value, which is given by Ohm's law, and which only depends on the electro-motive force of the battery and the resistance of the circuit.

It is evident that it is at the moment when this variable period ends that the inducing current should be broken in order that the induced current should have the greatest intensity possible, for a longer closing of the inducing current would only increase the consumption of zinc of the battery which diminishes the number of interruptions, and in consequence the number of induced currents produced in a unit of time.

Now, this does not take place with the ordinary circuit-breaker. On account of the elasticity of the pieces of which it is made, it makes vibrations of considerable amplitude, during which the relative durations of making and breaking contact of the inducing current are purely arbitrary, and have no connection with the values they should have to obtain the best effects of the coil.

A good circuit-breaker should fulfill the following conditions :

1. It should break the contact at the instant the variable period ends, when the inducing current has attained its maximum intensity.
2. It should remake the contact as quickly as possible after rupture, taking into account that the variable period of rupture has a much shorter duration than that of contact.

FIG. 104.—Deprez's improved circuit-breaker.

These conditions are fulfilled in the circuit-breaker described below. A is a little armature of soft iron movable around a stout spindle, E, which passes through its center. (See Fig. 104.) One of its ends is opposite the bundle of soft iron wires, G, and rests against a platinum pointed

screw, F. The inducing current arrives by this screw, traverses the armature to D, and reaches the coil by the pivot E and a small flexible strip of copper.

The antagonistic force is produced by a spring, R, attached at D to armature A, whose tension is regulated by the screw F.

The action is as follows :

As soon as the current is closed, the magnetization of the core passes, as mentioned above, from zero to the maximum, which it reaches in a very short time. There is thus an instant when the attraction of the core on the armature A is in equilibrium with that of the spring, and the least increase of this attraction causes a movement of the armature, and in consequence an immediate break in the current.

The armature, as well as the piece against which it rests, being very rigid, it is only necessary that this movement should be very small in order to break the contact. But as soon as the rupture takes place the spring R re-establishes the contact between the armature A and the screw F in an exceedingly short space of time, since the distance between the two is almost inappreciable, and the contact is again broken as before.

If it is desired to obtain the most energetic effects possible, the spring R should be given a tension sufficient to completely prevent any movement in the armature, and then be weakened gradually until the armature commences to vibrate. It is then certain that the contact is not broken until the magnetization of the core has reached its maximum.

FIG. 105. — Deprez's magneto exploder (small model).

To return to the exploder : In Figure 105 the armature of soft-iron B is fastened to a knee movable about the joint D. The armature consists of a plate of soft sheet-iron, B, bent at its ends so as to fit very exactly against the poles of the magnet A. This armature is wound with a thick wire nearly 2 millimeters in diameter, whose ends are fastened to the binding posts of the apparatus, which are themselves connected with a small model Ruhmkorf coil, capable of giving sparks 8 or 10 millimeters in length, with a battery.

To use the apparatus, the plate E is sharply struck and the screw of

the circuit-breaker of the coil is turned until the spark has a satisfactory appearance. It is easy to obtain a very hot spark 3 millimeters long, or a brilliant spark which may attain a length of 7 millimeters under favorable conditions.

When a feeble tension is given to the spring of the circuit-breaker, two sparks can be obtained, the first when the armature separates from, the second when it returns to, the magnet. The latter spark will also be very hot if its length is limited to about 2 millimeters. These two sparks develop sufficient heat to light a match moistened with kerosene.

M. Deprez has constructed a more powerful form, which is arranged slightly differently.

The armature is a plate of soft sheet-iron, 6 millimeters thick and 100 millimeters long, wound with a thick wire forming the coil. The whole is fastened to a brass frame movable around a horizontal axis, coincident with the axis of the magnet, which carries on each pole two pieces of soft iron, bevelled where the armature comes in contact with them.

There are thus always two of these pieces in close contact with the armature and two others which are not when the apparatus is at rest. If a strong blow is given to the handle the magnetization of the armature is not only suddenly diminished, but also reversed, since it is forced against poles of contrary name. More powerful results might be looked for in this apparatus, but they are not proportionately as great as in the smaller apparatus. Sparks exceeding 10 millimeters could not be produced, no matter what style of Ruhmkorff coil was used.

ARC LAMPS.

LIST OF REGULATORS.

MONOPHOTES.

Cances regulator.
Hedges regulator.

Jaspar regulator.

DIFFERENTIAL LAMPS.

Berjot regulator.
Weston regulator.
Pilsen regulator.
Hedges regulator.

Brush regulator.
Gulcher regulator.
Siemens regulator.

WITH DERIVED CIRCUIT.

The Gramme regulator.

De Mersanne regulator.

ARC LAMPS.

All arc lamps depend, for the light produced, upon the brilliancy of the voltaic arc between the ends of two pieces of carbon, and on the incandescence of the carbons themselves, when a current of electricity of sufficient power passes through them.

As, under these circumstances, the carbons waste away, until their ends are at such a distance apart that the electric current ceases to pass, and the light in consequence is extinguished, some arrangement must be made to cause their ends to approach each other, in proportion as they are consumed, so that the light will be maintained. This may be done by hand, but it is generally done automatically.

The apparatus for accomplishing this is called the regulator, and it is upon the sensitiveness of this regulator that the steadiness of the light depends, for a very small change in the length of the arc has a great effect upon the light.

These regulators may be divided into two classes:

1. Regulators which only permit a single lamp to be placed in a circuit, or *monophote regulators*.
2. Regulators with which 1, 2, 3 or more lamps may be placed in the same circuit, or *polyphote regulators*.

The latter class may be divided into three subclasses:

- a. Differential regulators*, in which the adjustment of the length of the arc is made by the differential action of the general current which produces the arc and a derivation of high resistance between the two carbons; their divergence then depends, at the same time, on the strength of the current and on the difference of potential at the base of the carbons, and

the equilibrium is established for each lamp when the intensity and the difference of potential have attained the value proper to good working.

b. Regulators with derived circuits, which must not be confounded with *differential regulators*, as the adjustment is not made by variations of the intensity of the general current, but only by variations of difference of potential at the terminals of the lamp. There is only a single electro-magnet, wound with fine wire, which serves to adjust the carbons; if there is another magnet its sole office is to separate the carbons at the moment of lighting, but it is not used in any way for the adjustment.

c. Regulators with a fixed divergence of the carbons, in which the readjustment of the distance between the carbons is effected automatically from time to time.

There is another type of arc lights, in which the carbons are placed parallel to each other, and are known under the name of electric candles. These may be—

1st. Candles with a refractory material, such as kaolin, between the carbons.

2d. Candles without kaolin.

All electric candles have a fixed distance between the carbons; that is to say, the distance apart of the carbons is not influenced by variations in the electric current.

The first of these classes has some relation to incandescent as well as to arc lights; the second belongs entirely to the arc light.

Monophote regulators.

CANCES REGULATOR.

This apparatus is constructed so as to work with continuous currents, and, as the movement of the carbons is proportional to their consumption, it follows that the position of the arc is always fixed.

Fig. 106 gives a longitudinal section of this lamp; *a* and *b* are the two carbons fixed to the holders *c* and *d*, formed of two frames, from each of which a pair of rods rises vertically. The lower carbon-holder *c* carries at its upper part two small pulleys, *e e*, around which pass the cords *f f*, one of the extremities of each being attached to a fixed point of the upper platform *g* of the apparatus; the other ends pass around the pulleys *h h* and are fastened to the top frame *d* of the other carbon-holder.

On this frame is placed a driving weight, *h*, around which is placed a cup loaded with a quantity of shot, and is guided in its descent by the rods *i i*; this weight, which forms a nut, fits on the central screw *j*, fixed laterally, but free to move on pivots at each end, that turn, one in a bearing formed in the top plate *g*, and the other on a step on the lower platform *k*. Under the action of gravity, the weight tends constantly to make

FIG. 106.

the carbon descend, turning the screw, and causing, on account of the arrangement of the cords, the lower carbon to be raised at a rate dependent on the diameter of the pulleys *e e*. It tends, therefore, to always bring the carbons in contact.

The two platforms *g* and *k*, connected by the four guiding-posts *i*, form the fixed frame of the apparatus. The lower platform carries two supports, *l*, which sustain the coil *m*, inside of which a tubular core can move freely. The upper part of this core is prolonged by the copper core *o*, the length of which is proportional to the magnetic intensity. From the lower end of the screw *j* depends a copper rod, *p*, passing through the axis of the core.

The weight of the core can be more or less neutralized by springs. It is this coil, placed in the principal circuit, which constitutes the regulating organ. For this purpose, the coil carries, above and below, cross-pieces, *q r*, rising and falling with it, and guided by the four rods *i i* of the frame. A regulating screw, *s*, in the upper piece *q*, and coming in contact with the upper part of the coil, serves to regulate the position of the core within the coil, and the position of the escapement-wheel which checks the movement, as will be shown further on ; a second regulating screw, at the other end of the same piece, limits the separation of the carbons, and, consequently, the length of the arc.

The lamp works as follows : The carbons being in contact, the current arriving at the terminal *u* passes through the frame to the upper carbon-

Fig. 107.

Fig 108.

holder and carbon, then through the lower carbon and holder, and the two rods *e e*, insulated from the rest of the lamp, but electrically connected by the cross-piece below ; these rods slide easily in sleeves, *v v*, connected by the conductor *w*, and communicating with one end of the coil *m*. The other end of the coil goes to the terminal *x* on the upper platform.

In flowing through the coil of the electro-magnet, the current magnet-

izes the core, which lifts suddenly and fixes the distance apart of the carbons, in the following manner :

The lower plate of the core carries an arm, y , Fig. 107, to which is attached a connecting rod, z , whose length can be regulated by an adjusting screw. The upper end of this rod is linked to the arm a' , of a cranked lever pivoted on the frame, the other arm b' is terminated by a curved piece, in which engages a finger, e' , fast on the frame d' , which is mounted loose on the extension p of the screw j . Within this frame is the toothed wheel e' , mounted loose within the frame d' , and fast on the rod p . This wheel which, therefore, turns with the screw, gears into the pinion f' , mounted on pivots within the frame. The spindle g' of the pinion carries also escapement, shown in plan, Fig. 108, which comes in contact with, or moves clear of, the spring h' , according as the carbons approach or recede from each other ; the special form given to this escapement causes it to act either as a brake or a stop. As will be seen, each recess in the wheel is separated by a wide path, on which the spring h' bears with sufficient power to stop the movement, when the magnetic variation, due to the approach of the carbons, has not been sufficiently great to bring the recess opposite the spring. At the moment of lighting, the core is lifted suddenly, raising with it the connecting rod z , which tilts the cranked levers a', b' ; the curved end of b' pushes the frame d' , which draws the escapement wheel against the spring h' ; the end of the spring enters one of the recesses in the escapement, and prevents this wheel and the pinion f' , which is fast with it, from being turned by the wheel e' . Then the pinion always gearing in the wheel e' forces this latter, by its travel with the frame d' , to move in a direction opposite to its normal motion, and as the wheel e' is fast on the screw j , the latter also revolves backwards, raising the weight h , and with it the upper carbon-holder, while, at the same time, the lower carbon-holder is forced to descend an equal quantity. When the arc is produced, the magnetic intensity of the coil is reduced in proportion as the carbons are consumed, the core tends to fall, and the escapement-wheel retiring from the spring h' , until it clears it, allows the carbons to advance in direct proportion to their consumption.

This operation constantly repeats itself, and the regular working of the apparatus is insured until the carbons are consumed or the lamp extinguished.

To change this lamp so that it will work with an alternating current, it is only necessary to make the diameters of the pulleys equal.

The lamp gave satisfactory results at the exhibition.

HEDGES REGULATOR.

This rather curious looking lamp resembles in principle the Rapiéff lamp. In the Rapiéff lamp, however, the carbons are moved by weights, but in

this lamp they fall by their own weight. In both lamps the positions of the ends of the carbons, and therefore of the arc, are determined by the point of intersection of the axes of the carbons. The construction is as follows: A and B, Fig. 109, are metal troughs of rectangular cross-section attached to the frame of the lamp, and so inclined to each other as to form the letter V. In these troughs the two round carbon rods can slide freely, meeting when there is no current at E. The trough B is rigidly fixed to the frame of the lamp, but the trough A, containing the negative carbon, is fastened to the frame by a pivot, on which it can rock, its position depending on that of the armature of the electro-magnet, shown in the figure, whose coils are included in the circuit. By this means as soon

FIG. 109.

as the current is established the armature is attracted, the two carbons are separated, and the arc is formed. The positive carbon B would fall if it were not retained by a small carbon, C', pressing lightly against it and making a small angle with B. This carbon, C', also slides in a trough fixed in such a position that the point of contact of the two rods is sufficiently near the arc to permit the smaller rod to be slowly consumed as the other is burnt away, thus allowing the latter to slide gradually down the trough, as long as the lamp is in action.

The trough A is furnished with a little adjustable platinum stop, E, which can be regulated at will by an adjusting screw. This stop presses against the conical end of the carbon and allows it to slide only in proportion as it is consumed. This stop is applied to the negative electrode, but is inapplicable to the positive electrode on account of the much higher

temperature of the latter, which would be liable to destroy it. For alternating the currents the stop may be used on both electrodes.

\ In order that the contact between the carbons and the troughs may be as perfect as possible each trough has a small contact-piece, F, which is grooved to fit the carbon; it is thickened at the free end, to increase its pressure, and hinged to the trough at the upper end. This arrangement has the additional advantage, namely, that the length of the carbon through which the current flows remains constant no matter what may be the length of the carbons, and their resistance is reduced to a minimum. Consequently, very long carbons, burning from ten to sixteen hours, may be employed without adding any increase of resistance to the circuit.

The length of the arc can be regulated by the adjusting screw G, by which the movement of the armature is limited.

Another form of lamp, very similar to the one just described, has a small cylinder of clay or other refractory material between the ends of the carbons. This cylinder is mounted on a horizontal axis and can be rotated by a worm and worm-wheel, actuated by an endless cord passing over a grooved pulley. One carbon-holder is rigidly fixed to the frame of the lamp, the other is mounted on an axis, so as to enable the length of the arc passing over the cylinder to be regulated by the action of an electromagnet, attracting an armature in opposition to the tension of an adjustable spring.

There are certain points of similarity between this latter lamp and the Soleil lamp.

THE JASPAR REGULATOR.

The peculiarity of the Jaspar system of electric lighting, as seen at the exhibition, is that the direct light of the lamp was screened from the eye, the regulator being placed at the bottom of a cylinder, with opaque sides, while the luminous rays escaping from the top struck a large white umbrella-shaped reflector, and were thus diffused, producing a general illumination soft and pleasing to the eye.

This method of illumination will be further described when I come to speak of the Jaspar system of the "canalization of light."

In the Jaspar regulator the weight of the positive carbon-holder acts as the motor. Fig. 110 is a side view showing the mechanism; Figs. 111, 112, 113, and 114 are, respectively, two vertical and horizontal sections. The frame of the lamp consists of two platforms, A A', connected by four bars, *a a*. The negative carbon-holder C is formed of a copper tube traversing the upper platform, the lower part of which slides in a second tube, C', fixed on the base A. This lower portion is a hollow cylinder of soft iron. In the middle the tube C has a longitudinal slot wide enough to allow part of the circumference of the grooved pulley D to pass: around

this pulley is wound the cord d , which descends in the tube C' (see Fig. 112), and carries a weight, P , that keeps it stretched. This weight abuts against a transverse piece, t , in such a way that when the cord is wound up the weight in rising lifts the carbon-holder. The grooved pulley is fixed on a small drum, T , supported by the two brackets b b , on which is also placed another grooved pulley, D' , of double the diameter of D . On D' is wound the cord d , attached at its lower end to the piece E , Fig. 111, which forms the base of the positive carbon-holder. It will be seen from the way the cords are wound that the weight of the positive carbon-

FIG. 110.

holder tends to raise the negative carbon-holder, and that the latter will only move through half the distance of the former. This difference corresponds to the unequal consumption of the carbons, and the position of the arc will remain fixed.

On the drum T is wound a third cord, attached to the weight P' , which can be adjusted on its rod by the screw V . This weight helps to counter-balance the positive carbon-holder, which always tends to rise. Its posi-

tion is regulated in such a manner that its influence is the greater as the current is more feeble, so that the regulator can be used with very different intensities of current.

The positive carbon-holder is a copper tube, furnished with a clip, to which the carbons are attached.

FIG. 111.

FIG. 112.

Figs. 115 and 116 show details of the holder, by which the point of the upper carbon can be brought into accurate contact with that of the lower.

The tube F, Fig. 111, slides in the tubular guide H, fixed to, but insulated from, the upper platform; alongside it is a small tube, I, filled with

mercury into which dips the rod K, which transmits the current to the carbon-holder.

The negative carbon-holder also carries a rod, L, terminating in a small piston, M, which can move in the tube N, filled with mercury ; as the piston does not fit the tube tightly this arrangement acts as a brake, similar to the glycerine dash-pot in the Brush regulator.

On the tube C' is wound a wire, forming a solenoid and intended to produce the separation of the carbons and to counterbalance the effect due to the weight of the positive carbon-holder. The working of the regulator is as follows :

The positive pole of the generator is in communication with the positive carbon through the tube I, containing mercury, the rod K, and the car-

bon-holder F. The negative pole is connected to the solenoid, the tube N, the rod L, and the negative carbon-holder. The points of the carbons are in contact ; when the current passes the solenoid attracts the iron rod forming the end of the negative carbon-holder and tends to draw it down. The weight of the positive carbon-holder, regulated by the weight P', acts in an opposite direction, making equilibrium between the two opposing influences ; and the separation of the carbons would remain unaltered if the action of the solenoid were constant. In practice this is not the case ; it varies with the position of the iron rod, and the distance between the carbons tends always to increase.

To counterbalance this augmenting action a counter-weight is placed

between the weights of the large pulley, acting in an opposite direction, and the movement of which increases at the same time as that of the solenoid. The distance between the carbons consequently remains the same, all the time the lamp is in action.

This regulator combines three striking characteristics :

1. The counter-weight P, allowing the employment of the lamp with currents of different intensity.
2. Counter-weight last mentioned compensating for the variable action of the solenoid.
3. The pendent rods acting as brakes and preventing any sudden variation in the movement of the carbons.

CANALIZATION OF LIGHT.

It occurred to M. Jaspar that, instead of dividing the circuit and obtaining a number of lights on one circuit, it would be practicable and more

FIG. 117.

FIG. 118.

economical to distribute it from one center by suitable optical apparatus. Two facts support this idea, one being that the intensity of light is inversely proportional to the square of the distance, due to the divergence of the rays. Parallel rays, however, can be projected to considerable distances, without much loss. The second fact is the loss in intensity, due to the division of the electric light. If by division a better distribution of light is obtained, the sum of the intensities of all the smaller lamps is far below that which could be produced by concentrating the whole current in one lamp. The system proposed preserves the advantages of a single light and at the same time distributes it to different points, by grouping around the luminous point a crown of lenses, which receive the rays

and refract them in as many beams as can be reflected in useful directions, and which direct them through openings in the walls, upon large white screens placed in the apartments to be lighted. These screens act like electrical windows distributing the electric light, like ordinary windows do daylight into the room. Figs. 117 and 118 show how these lenses are arranged; should the position of the luminous point change it can be brought to its proper position by the lever L.

This system of distribution is applied at M. Jaspar's establishment at Liege, and is said to be very effective. The works were originally lighted by forty gas burners, costing about 25 cents an hour; with the electric light this cost was reduced to about 10 cents an hour, divided as follows:

	Cents.
Carbons	4
Coal oil and engineer.....	3
Interest and depreciation.....	3
Total	10

According to the inventor, these screens act precisely like clouds, which, when the sky is overcast, diffuse and filter the sunlight and soften the shadows produced by a luminous atmosphere.

Differential lamps.

THE BERJOT REGULATOR.

This lamp consists of a casing, as shown in Fig. 119, the clock-work being inclosed in the frame A, B, A', B', at the top and bottom of which are four flat springs, R, R, R, R, suitably regulated, and on which react, under varying conditions, two electro-magnets, E, E'. One of these magnets tends to raise the case, the other to work the mechanism.

The first, E, is wound with coarse wire, and is placed in the same circuit with the carbons; the other, E', is wound with fine wire, and is in a derived circuit. They are straight magnets, whose cores are cut in the middle, one-half forming the armatures. In this way are combined the reciprocal action of the solenoids and the attractive action of the cores.

The case containing the clock-work supports the weight of the upper carbon-holder, which is adapted to a long rack, C C, gearing with the first wheel of the clock-work by means of the pinion P. A second counter-weight, M, acts conjointly with the upper carbon-holder and tends to pull down the case, which would always tend to be lowered if it were not resisted by the magnet E, which locks it in a fixed position. The carbon-holder itself would always tend to fall if it were not held by the clock-work, of which the last wheel, D, is held by the spring-brake F, fixed to the frame. As this brake may be raised or lowered by the action of the magnet E', the rack of the upper carbon-holder is free to move when the magnet E' is in action, the result being that the two carbons can approach

each other; this happens whenever the intensity of the current traversing the arc is sufficiently weakened to allow the magnet with fine wire, E' , an excess of power over the other.

FIG. 119.

This approach is effected, moreover, conjointly with that of the lowering of the case containing the clock-work, but as soon as the carbons have approached sufficiently near to restore the strength of the current at the arc, the magnet E with coarse wire again raises the case, and the magnet E'

releasing the brake prevents the clock-work from moving until the arc is again weakened.

The apparatus is so sensitive that the case seems to be in a continual state of vibration, and as the stoppage of the clock-work is never sudden, on account of the delicate action of the brake, the smallest difference of intensity can be corrected without showing the least change in the steadiness of the light. When the rack arrives at the end of its course; that is to say, when the upper carbon is consumed, a stud, which it carries, presses and shunts the current into the circuit of other lamps. When it is desired to have the lamps burn for a long time, an arrangement of several

FIG. 120.

racks is used, which come into action one after the other, somewhat similar to that used in the Brush lamps.

The mechanism of the lamp is simple, sensitive and certain, and its

details have been well worked out. A modification of this lamp, combined with the Serrin lamp, is employed in the French light-house service.

THE WESTON REGULATOR.

This lamp is shown in perspective in Fig. 120. The mechanism occupies a very small space. The lower carbon is fixed; the upper carbon slides freely in the tube at the upper part of the apparatus; when there is no current the upper carbon rests on the lower.

FIG. 121.

In Fig. 121, *M M* is an electro-magnet of special construction, and *A A* is its armature, which only has a to-and-fro vertical motion, being held by two flat steel springs fastened to the frame.

At rest, the upper end of the armature is a little below the upper core of the electro-magnet; the attraction of the latter will then tend to raise the armature and the clutch *C*, which is fastened to it, but this clutch is so made that it raises at the same time the upper carbon-holder *R*, by wedging it, nearly in the same way as in the Brush regulator.

The action of the magnet on the armature is regulated by a spring, *S*, whose tension can be varied by a screw, which acts on the attached lever *L*.

To avoid all sudden movements, the lower end of the armature carries a little piston, *P*, moving in a cylinder, *G*, filled with glycerine. The piston is composed of two superposed disks, each having three small triangular grooves on their circumference. By making these grooves coincide more or less closely, a larger or smaller opening is left for the passage of the glycerine, and thus the quickness of motion of the armature can be regulated at will.

The electro-magnet is wound with two wires, one thick and short, the other fine and long, but in reality there are three coils on each core, as shown in the sketch on the left of Fig. 121. The two coils of fine wire belong to the same circuit and are mounted in derivation; the thick wire is placed in the circuit of the carbons and is traversed by the main current.

The connections are so made that these two coils tend to produce opposite polarities in the core.

The working of the apparatus is as follows: At rest, the carbons touch and form a short circuit; the current arrives by the left terminal, traverses the thick wire of the magnet, passes through the carbons and returns through the frame of the lamp to the right-hand terminal. The magnet, being strongly magnetized, raises the armature, drawing the clutch C and the rod R R, and establishes the arc. The fine wire is likewise fastened to the terminals of the lamp and forms a derived circuit, which will be traversed by a current whose intensity will be proportional to the length of the arc. As soon as the resistance of the arc increases, this fine coil will weaken the intensity of the magnet, the armature will descend, the carbons will approach, and the derived current will become less intense again. If for any reason the arc should become extinguished, the armature falls, the carbons retouch, and the arc is re-established.

The mechanism is exceedingly simple, the apparatus is very sensitive, and the light produced is very steady.

THE PILSEN REGULATOR.

This lamp is the invention of two Austrian engineers, Messrs. Franz Krizik and Ludwig Piette, but takes its name from the town of Pilsen, in Bohemia, where it was first brought out.

In this apparatus two magnetic attractions, coming from the same source, regulate the light without any intermediate mechanism and without the application of any force, except that due to the electric current.

The construction of the lamp is extremely simple, and the mechanical resistance and other obstacles which interfere with the movement of the carbons have been reduced to a minimum.

The current before entering the lamp is divided into two parts, each traversing one of two superposed solenoids, in which slides an iron rod or core of a special shape. The principal current passes through the first or upper solenoid wound with thick wire, while the derived current traverses the other solenoid wound with very fine wire. The relative resistances and the number of windings of these two solenoids are so calculated that when the arc has attained a fixed and determined resistance, the rod or core remains in equilibrium, under the influence of the two solenoids.

When the resistance increases the equilibrium is broken and the regulating action takes place.

When a cylindrical iron core of the ordinary form is placed inside a solenoid through which a current passes, the core takes up a balanced position in the coil, and, when moved from it, always tends to return to it.

FIG. 122.

Thus with two solenoids, *M*, *S*, Fig. 123, the cylindrical core will take a position proportional to the power of one coil over the other, and when the current alters in either coil the core will take up a new position, always tending, however, to return to the old one when the current again becomes normal.

By using a spindle-shaped core of any of the forms shown in Fig. 122

FIG. 123.

there is no tendency to take up a particular balanced position. It has a longer range of free movement and can be used to feed the carbons directly.

In the figure the spindle-shaped core is shown at different points of its

FIG. 124.

range, and in each of these positions there is no tendency for it to move up or down.

The following is the construction of the lamp: (See Fig. 124.) The wire from the negative pole of the generator is attached to the terminal marked—and goes from thence through the main coil *M*, by means of the sliding contact-spring *S*. The current then splits, part going through the small coil *A* and the rod *D'*, insulated from the frame of the lamp, thence to the lower carbon-holder by the contact-roller *r*. The positive current enters at the terminal *+*, and goes to the frame and upper carbon. The shunt circuit *G* is of thick German silver wire, connected to the iron frame of the magnet *A*. From thence, a fine coil of German silver wire, of about 130 ohms resistance, is wound round the outside coil of the lower solenoid *M'*, and the end of this coil is connected to the contact-screw *n*, and to a comparatively thick copper wire of low resistance, coiled inside the German silver wire on *M'*. The other end of this copper wire passes to the metal frame of the lamp and thus completes the shunt circuit.

The object of this supplementary resistance is to make up a total resistance, together with the copper coils inside *M'*, equivalent to the lamp when burning, and to avoid heating, when all the main current passes through that shunt or partial shunt circuit.

After all the wire is coiled on *M*, the insulator is scraped off a strip $\frac{1}{2}$ inch wide, leaving a ridge of bare copper wire, and connection is made by the contact-spring *S*, which slides up and down the fixed rod. In this way the pull of the coil *M* can be adjusted and the length of the arc regulated.

The small magnet *A* is to automatically short-circuit the high resistance coil *M'*. As before mentioned, a wire from *M* passes through this magnet. The frame of *A* is made of a bell, crank shape, so that the armature at the top is a prolongation of the bottom pole, thus utilizing both poles. This armature is pivoted in the center and the free side is weighted, so as to make contact with the adjustable contact-screw *n*, fixed to the insulated bracket at the side of the frame of *A*. Thus, by means of *A*, the high resistance wire on *M'* can be automatically cut out, when the carbons are consumed or when there are none in the lamp, and the main current then passes through the thick copper wire on *M'*. This is effected as follows: One end of the fine wire shunt coil, on the outside of *M'*, is connected to the wire of *G*, and to the metal frame of *A* at bottom; the other end being connected to the copper shunt coil and insulated bracket and contact-screw. When the lamp is burning the main current passes through *A* and attracts the armature retaining it, and thus breaks the contact at *n* and adds the fine wire coil to the shunt circuit, which then balances the resistance of the lamp.

When the carbons are consumed this electro-magnet, *A*, cuts out the

lamp. This is done by inserting a small insulating piece in the guide-rod D' at I , so that when the lower holder H rises to this insulated piece, I , the roller r on that side becomes insulated from the rod D' , and the magnet A is cut out from the circuit, the armature is released, and the weighted side remakes contact and short-circuits the fine coil on M' .

The upper coil then preponderates and pulls the top carbon up, thus completely separating the two carbons and breaking the arc; the current passing through the thick shunt coil and wire A .

During the operation the supplementary wire and derived circuit maintain the current through the arc (which would otherwise be broken by the insulation at I), thus allowing the main coil M to expend the carbons and preventing the burning of the metal carbon-holders.

The frame of the lamp consists of brass tube mounted between two brass plates, with two iron rods joined across the bottom. The iron core fits loosely inside a brass tube, which again fits loosely inside the tube of the frame and is guided by contact-rollers, so that it moves with very little friction. The weight of the iron core is counterbalanced by that of the bottom carbon-holder, by means of cords attached to metal rods and passing over pulleys.

The metal rods are used instead of cords near the arc, to prevent

FIG. 125.

scorching. One of the carbons is fixed to the core-tube, the other to the lower carbon-holder.

If a lamp with a fixed focus is desired the pulleys are made double, one being twice the diameter of the other; the cord that passes over the larger pulley is connected to the top electrode, whilst that passing over the smaller pulley is connected to the bottom electrode. The different sizes of the pulleys allow the carbons to feed together in proportion as they are consumed.

The same principle is applied to a horizontal lamp. Fig. 125 is a diagram of the connections, C being the iron core, *r r* the contact-rollers and M M' the solenoids. One carbon is fixed to the end of the tube C, and the other to the pivoted arm D. Such a lamp can be used to advantage where the ceilings are low.

Another lamp, for street lighting, is made, in which the counter-balances are reversed and the coils are placed at the bottom beneath the lamp. This arrangement permits the regulating coils to be safely protected, and avoids shadows on the globes.

The Pilsen lamp has the merit of simplicity of construction and great steadiness in working.

HEDGES REGULATOR.

The differential lamp of Mr. Killingworth Hedges resembles, in many particulars, his single light lamp already described. Fig. 126 shows the

FIG. 126.

modification, when it is desired to burn a number of lamps in series. The carbons are separated by the attraction of a solenoid upon an iron cylinder, H. This cylinder is attached by a non-magnetic metal rod to

the armature of an electro-magnet wound with fine wire, mounted in a derived circuit between the terminals of the lamp. The action of this magnet is opposed to that of the solenoid. When the circuit is established the carbons are separated by the action of the solenoid on the iron cylinder, and the distance between the ends of the carbons is determined by the difference between the action of the solenoid and of the electro-magnet. If the resistance of the lamp increases, either by the lengthening of the arc or by bad contacts, a greater quantity of electricity passes into the derived circuit, and the arc is shortened by the action of the latter. In other words, the length of the arc is determined by the position of the armature of the electro-magnet between the poles, the latter and the solenoid, which position is determined in its turn by the difference between the strength of the current passing through the solenoid and that traversing the electro-magnet.

THE BRUSH REGULATOR.

The leading feature of this regulator is that the carbon-holder has a rod which slides through a friction-clutch, which serves to separate the carbons and produce the arc, when the current is established. The lamp may be provided with one, two, or more sets of carbons, the principle being the same in each. A lamp with two sets of carbons will be taken for the purpose of description. The general appearance of such a lamp is shown in Fig. 127. The lower carbon is fixed, consequently the luminous point does not remain in the same position, but varies as the carbons are consumed. The upper carbon and holder are movable, and as they descend by their own weight contact is made between the points of the carbons.

Fig. 128 shows the details of the mechanism for lifting the upper carbon and thus producing the arc. A hollow helix or solenoid, wound with fine wire, is placed in the circuit, within whose cavity moves freely a core of soft iron. The electric current passing through the solenoid tends to lift this core, which is rigidly attached to a bar, E^2 , and the movement of this bar, due to the varying attractions of the solenoid, is imparted by a link and lever connection to the lifter D , which will have an up and down movement in exact concert with the core.

The lifter D may be so constructed as to separate the carbons successively or dissimultaneously, by being so balanced that any slight difference in the weight of the two upper carbons or their holders shall result in one being lifted before the other.

In order to properly balance the attractive force of the magnet a coiled spring, F , is employed, and, to insure a steady motion to the magnets and carbons, a dash-pot, G , filled with glycerine is used.

Fig. 129 is a detached view of the parts operating to lift the carbons. C C' are rings surrounding the carbon-holders B B; each ring is arranged to be lifted from a single point, thus tilting it and causing it to grasp and lift its inclosed carbon-holder. This tilting and lifting movement is imparted by the lifter D.

FIG. 127.

The upper part of the movable carbon-holders is hollow and filled with glycerine; in them is a rod supporting a piston and fastened above, as shown in Fig. 130. As the piston nearly fills the tube of the carbon-holder it acts as a brake to prevent the carbon from descending too suddenly.

Fig. 131 shows a diagram of the system which cuts any lamp out of the circuit, without affecting the other lamps. X and Y are the two terminals of the lamp, H the solenoid for regulating the arc, and T the electro-magnet of the cut-off. This electro-magnet is wound with two wires; one

FIG. 128.

not shown, is of fine wire placed in the same derived circuit as the fine wire of the solenoid; the other, short and thick, leading from X to Y by B and R, but interrupted at M. While the current is normal, the cur-

rent which traverses the fine wire of the magnet *T* is not strong enough to raise the armature *A* ; but, if the are becomes too long, the intensity in the fine wire becomes great enough to attract the armature *A* ; the con-

FIG. 129.

tact is made at *M* ; the principal current then passing through the thick wire keeps the armature raised ; the current then no longer passes through the lamp but goes from the terminal *X* to *Y*, through the resistance *R*, the contact *M M'*, and the thick wire. In Fig. 128 this electro-magnet is shown at *M'*.

The action of the lamp is as follows : When the core, Figs. 128 and 129, rises, the lifter *D* is raised and the carbons are lifted as previously described, but as one of the jaws of *D* is larger than the other, one carbon will be lifted before the other, and the arc is established between the carbons which are the nearest together.

A time arrives when this latter carbon can no longer be lifted, being consumed ; the arc then lengthens, the second carbon descends and makes contact ; the arc is re-established between the second pair of carbons.

It should be said that the solenoid *E* is wound with two wires, one fine and long, in a derived circuit, the other short and thick, in the main circuit wound in an opposite direction. This action is the same as that in lamps previously described.

In connection with the Brush system of electric lighting is a current

governor, consisting of a pile of carbon plates, H, Fig. 132, connected in series and mounted in a derived circuit, of a solenoid, E, wound with

FIG. 130.

FIG. 131.

thick wire in the main circuit and with fine wire in the derived circuit, and of a dash-pot, *F*, to prevent sudden movements of the lever *D*, and thus avoid abrupt variations of resistance in the carbon-pile *H*.

Within the solenoid is a movable iron core, pivoted to the lever *D*, carrying an adjustable weight, *e*: the free end of the lever carries the body of the dash-pot *F*, and a screw, *d*, by which its downward movement is adjusted; the piston of the dash-pot *F* is attached to the frame of the apparatus by means of its rod, and is provided with a valve opening downward. When the dash-pot is filled with glycerine, its piston and valve allow the lever *D* to move downward freely, but retard its upward movement.

The operation of the apparatus is as follows (See also Fig. 133): The

FIG. 132.

terminals *p n* of the derived circuit are connected with the field-magnets of a dynamo. The course of the derived circuit is then from the terminal *p*, through the piles *H H*, the outer portion of the solenoid *E*, to the terminal *n*. The binding posts *P N* are in the main circuit, so that the main current shall pass through the thick wire of the solenoid, in the same direction as the derived circuit. The weight *e* is so adjusted that when the dynamo is working to its full capacity, and the normal working current is passing through its portion of the solenoid *E*, the inclosed iron

core, lifted by the solenoid, shall just sustain the lever D while subjecting the pile H H to little or no pressure. If now the resistance of the working-circuit be lessened from any cause, the current will be correspondingly increased in the solenoid E, and the inclosed core will be drawn upward, raising the lever D and subjecting the resistance-piles H to a pressure corresponding to the increase of current in the main circuit. The current will then be shunted from the field-magnets of the dynamo, until the main current is reduced to nearly its original strength. Some

FIG. 133.

increase of current strength is, however, required, in order to maintain a suitable pressure in the piles H H. It is, in order to render this necessary excess of current as small as possible that the derived current is passed through the fine wire of E, thus assisting to maintain the pressure on H H.

The office of the dash-pot has been described, but the function of the valve has not been indicated. Suppose a number of lamps in circuit, and the latter, as frequently happens in practice, becomes for an instant broken, then, owing to the valve, the lever D drops at once, and the resistance in the derived circuit increases, so that when the carbons in the lamps have come together again and completed the main circuit, the full power of the dynamo will be available to separate the carbons, and, owing to the slow upward movement of the lever D allowed by the dash-pot, sufficient time is given for the carbons to become fully separated before the derived circuit can act; but if the lever D had not been allowed to fall materially during the instant the main current was broken, the abnormally great current developed when the circuit was closed and before the carbons had time to separate, would further raise the lever D and unfit the dynamo for developing its normal current.

The Brush regulator has been very successful, and has been widely used,

both in this country and in Europe. In this lamp, as in many others, the carbons are coated with copper, thus increasing their conductivity and confining the consumption to their ends.

THE GULCHER REGULATOR.

In the Gulcher system, each lamp is placed in a derived circuit instead of being arranged in series, as in most other systems; from this point of

FIG. 134.

view it might be considered as belonging to the monophote class; but, as the regulators act as solenoids of different resistances, it seems more proper to include this regulator in the differential class. The fact that each regu-

lator reciprocally regulates the others, is a remarkable part of this system; they are, moreover, distinguished for simplicity of construction, for the whiteness of the light they furnish, and for the low tension currents employed; consequently their use is free from danger of heavy shocks, and only ordinary care has to be taken with the insulation of the cables; on the other hand, these cables have to be of large diameter, thus somewhat increasing the cost of installation.

The regulating mechanism consists of a pair of bearings, C, Fig. 134, supporting the pivots of a metal ring, D, which carries an electro-magnet, E, free to oscillate on these pivots; at the base is the insulated terminal F, connected to the positive pole of the generator; the current is led to the bearings C, also insulated, and thence by the coil to the core of the magnet, whence it flows partly by the spring G, which is in contact with one end of the magnet and in metallic connection with the case, and partly to the rod H, in contact with the other end, this rod being pressed against the magnet by a small spring.

The upper carbon-holder is attached to the rod H; the current passing through H flows through the carbons, the lower carbon-holder, and thence by a wire or other conductor to the other terminal, I.

Both carbon-holders are movable and are connected by a cord, R R', passing over a pulley, S, so arranged that the point of contact of the carbons will remain fixed.

The poles of the electro-magnet E are curved, forming parts of circles whose centers are in the pivots of the ring D. One pole, J', to the right extends downwards and terminates in a projection, under which is a small iron block, K, attached to the frame. The lower end of the spring G is furnished with another small iron block, L, making contact with the pole J'. Through the top of the case passes the adjustment-screw M, prolonged into a spindle, X, against which the pole J' is pressed, when no current is passing, by the spring N, connected to the bent lever O, which is pivoted to the insulated bearing C. The upper end of the spring bears against a screw, P, and its tension is regulated by the screw Q, insulated from the lever O. A perspective view of the regulator is shown in Fig. 135.

The operation is as follows: As soon as the current passes, the electro-magnet E attracts the rod H to the pole J, and at the same time the part J' of the other pole is attracted to the block K, thereby causing the magnet to turn on its pivots and raise the carbon-holder H, because of its contact with the curved face of the pole, the motion being steadier and more uniform than could be imparted by a rack and pinion—the carbons are separated and the arc is produced.

As the carbons are consumed, the arc lengthens, the resistance increases, the power of the magnet diminishes, and the pole J' separates from the block K; the carbons approach each other until the pole J' is arrested by

FIG. 135.

T T. Upper carbon-holder.
 T'. Lower carbon-holder.
 E. Electro-magnet.
 R. Pulley.
 L. Spring acting on magnet E.

L'. Spring with magnetic brake.
 V. Adjustment screw.
 M. Bearing supporting magnet.
 b. Stop for spring L.

the stop X , the position of which has been carefully adjusted. As soon as this condition has been established the magnet E has no further movement and the carbons continue to burn until they are at a distance apart corresponding to the greatest intensity of the light.

As soon as further consumption increases this distance, the power of the magnet E becomes too small to sustain the rod H , which slips down until the power of the magnet is again increased sufficiently to hold it; should it continue to fall, the power of the magnet would increase until the pole J' would again be attracted by the block K' , and the preliminary process would be repeated. In practice, however, it is found that after the lamp has been started the magnet remains stationary, the weight of the carbons and holders and the consumption of the carbons being sufficient through the varying action of the magnet, to secure the automatic working of the lamp. The faces of the poles of the magnet, the rod H , and the block L , are faced with thin brass, to diminish the attractive force of the magnet and to facilitate the sliding of the rod H ; this makes the action of the regulator much smoother and checks irregularities in the light. The block L acts as a magnetic brake, when the lamp is started, and secures a smooth and easy movement.

The peculiarities of this regulator render it suitable for being used in groups in the same circuit, and one lamp acts as regulator of the second, the first and second as regulator of the third, and so on. This regulating action depends on the positive motion of the electro-magnet and upon the quantity of current flowing through the circuit.

To explain this, suppose the simple case of two lamps, in parallel circuit, Fig. 136, exactly like incandescent lamps—Edison's, for example:

FIG. 136.

The lamp A , being lit first on the passage of the current, if, in the lamp B , the separation of the carbons should be too great, the strength of the current will increase in A , and cause the carbons in B to approach, and *vice versa*; for, should there be too great a separation of the carbons of the regulator A , it will cause the magnet of B to increase the distance of

its carbons by the increase of the strength of the current in its derived circuit, and consequently the total current will be weakened until the magnet of *A* can no longer retain its carbon-holder, the carbons of *A* again approaching each other. Then the derived current of *B* is weakened in its turn, the magnet retakes its position of rest, and so on.

Now, if another lamp, *C*, be introduced in the derived circuit, these two lamps, *A* and *B*, can be considered as a whole (*A* + *B*) regulating *C* and being regulated, reciprocally, by it; *A* acts in the same way on *B* + *C*, and *B* on *A* + *C*. This, which takes place with these lamps is produced in the same way for any number whatever, simply by placing them in derivation and without the use of any accessory mechanism.

The following is the manner in which the inventor arranges the cables for working a number of lamps on the same circuit :

Let *m* be the number of lamps fed by the generator, Fig. 137, the total length of the cables being known. The diameter *D* of the principal current is first calculated, then a diameter, *d*, is found by the formula, $\frac{\pi D^2}{4} = \frac{m \pi d^2}{4}$ or $d = D \sqrt{\frac{1}{m}}$, and a cable is formed of *m* wires of the diameter *d*, whose cross-section has the same surface, and, consequently, the same conductivity as a section of a single wire of the diameter *D*. This cable is first attached to one of the poles of the generator; for example, to the positive pole, and then is led to the first lamp, where one of the wires is connected to the lamp; to the second lamp a second wire is attached, and so on.

FIG. 137.

The cable attached to the negative pole is led in the same way, except that the different wires are attached to the lamps inversely; that is to say, the first wire is attached to the last lamp and the last wire to the first lamp, as shown in the figure. The resistance of the conductors is thus the same for each lamp, for the paths of the derived currents are geometrically equal, and the sections of the conductors correspond, everywhere, exactly to the quantity of current traversing them.

As the main current is equal to the sum of the derived currents, and, as for *m* derived circuits of *s* strength, $S = ms$, a current of the strength $S =$

ms flows through the principal circuit to the first lamp. From the first to the second lamp a current of $\frac{m-1}{m}s = (m-1)s$; from the second to the third a current of $\frac{m-2}{m}s = (m-2)s$, and so on; but, at the same time, the section of the conductor diminishes proportionately, since a cable of m wires of equal size has been employed as conductor and at each derived circuit it has been diminished by one wire.

The increase of the strength of the current will follow analogous variations in the return circuit, whose section is also exactly in proportion to the strength of the current.

In addition to the whiteness of the light, this system has the advantage of great steadiness of the light, simplicity of the regulators, the number of lamps which can be placed in one circuit, the facility with which one lamp can be lit or extinguished without affecting the remainder, and that the force required to drive the dynamo is proportional to the number of lights in action at a given moment.

THE SIEMENS REGULATOR.

The principle on which differential lamps are constructed has been so fully described in previous apparatus that it is not necessary to repeat it again here. Fig. 138 shows the theory of the construction of this regulator. The current arrives at L , is divided into two parts, of which the

FIG. 138.

weakest traverses the upper solenoid T , wound with fine wire, and escapes by $b L'$, to go to the next lamp. The main current traverses the solenoid with thick wire, R , the lever $d a$, the carbons $g h$, and at b is united to the other current. The resistances of the solenoids T and R are such that only about one one-hundredth part of the current traverses T . As the attraction of R or T preponderates, by variations in the resistance of

the arc, the soft-iron cores $S S'$ will be more or less lowered or raised, and thus will diminish or increase the length of the arc.

Fig. 139 shows the actual form of the lamp; the movement of the lever c, d, a acts on a pinion and rack, which allows the carbons to approach; a pendulum and balance-wheel prevent the carbon from falling too rapidly,

FIG. 139.

and a little air-pump fastened to the rod traversing the solenoids softens the movement of the rod and prevents vibrations due to alternating currents. The adjustment is made by raising or lowering the upper solenoid. All the mechanism is placed in the upper part of the lamp, in a copper cylinder; thus but little shadow is cast below. Ten to twelve lamps can be placed in the same circuit; and lamps of smaller intensity can be used, by placing them in derived circuits.

Regulators with derived circuit.

THE GRAMME REGULATOR.

This apparatus consists of two parts, one causing the carbons to approach each other, as they are consumed, the other to withdraw them, when the current first passes, so as to form the voltaic arc.

In Fig. 140 the lower carbon-holder is fixed, the upper one is movable, consequently the position of the arc changes; but these conditions are not essential; other forms of regulator are made with the luminous point fixed. But all forms possess the same essential parts of mechanism, viz: a powerful motor, an intermittent electro-magnet, a withdrawing movement and a carbon-holder with eccentric spring.

The mechanism is contained in a cylindrical case fixed to two end disks, solidly connected together with tie-rods.

The electro-magnet A A is attached to the tie-rods; its armature, C, is fixed to the upper part of the rods E E, which traverse the whole length of the regulator and are prolonged to the lower carbon-holder G. Two springs, R R, force the armature C away from the magnet A A, when the current does not pass. The current arrives by the positive terminal, which is in communication with the whole of the regulator, passes by the positive central rod D, traverses the upper carbon, the voltaic arc, the lower carbon, the negative rods E, the magnet A A, and leaves by the negative terminal, which is insulated. It is evident that, as soon as the current passes, the magnet A A, with the armature C, will be attracted, and thus will lower the lower carbon. This movement is not only independent of the regulating mechanism, but is also removed as far as possible from it, so as to avoid the perturbing influence of one magnet on the other.

The rod D is very heavy; it carries a rack on one side and its end is the upper carbon-holder F.

An electro-magnet, B, wound with a wire of high resistance, is fastened to the tie-rods of the regulator. This magnet carries a jointed piece, K, on which is hinged a lever, L. The latter is kept horizontal by the spring U. The armature I of the magnet B is of one piece with the lever L. A screw, M, and a little plate S, are placed at the other end of the same lever. The mechanism is completed by a spring, N, insulated from the rest of the apparatus and placed on the piece K, with a piece of hard rubber between. The current which traverses the magnet B is taken at P, on one of the negative rods, then, by means of a screw in communication with the spring N, it passes through the screw M and lever L. The magnet B is thus in a derived circuit. So long as the principal current preserves a certain intensity the plate S locks the clock-work movement and prevents the carbon-holder D from descending; but when this intensity is weakened, the current increases in the derived circuit around the magnet

B, the armature I is attracted, the lever oscillates, and the plate S rising, permits the wheel-work and, consequently, the rod D to move. The

FIG. 140.

carbons approach and the arc diminishes in length. The screw M then leaves the spring N, and the current ceases to traverse the electro-magnet

B. The armature I, pulled by the spring U, regains its horizontal position, and the contact of the screw M with the spring N again takes place. And if the arc is not exactly at its normal length, the same action is repeated, until this result is obtained. This intermittent action of the magnet B has for a principal advantage the suppression of the variations of the light, so noticeable in many other regulators.

This is easy to explain. In all regulators actuated by a powerful motor the movement of approach of the carbons is obtained by the aid of an electro-magnet and a powerful opposing spring. When the armature is attracted, the distance between the poles and the armature becomes diminished; the equilibrium between the tension of the spring and that of the electro-magnet becomes broken during a certain time; the carbons approach a little more than they should, and the arc becomes too short, before the wheel-work is locked. The variations of the arc lead naturally to variations of the intensity, and the amount of light changes accordingly.

With an intermittent action of the electro-magnet, as soon as the equilibrium is destroyed, the locking mechanism acts and the carbons approach a few hundredths of a millimeter; then the influence of the electro-magnet becomes annulled, the spring pulls back the armature to its first position and causes a new break of equilibrium, which causes a fresh unlocking.

The sensibility of the apparatus is such that it works in a continuous manner, exactly as if it were moved by automatic mechanism, instead of being dependent on two forces in equilibrium. The regulator is well and accurately made.

THE DE MERSANNE REGULATOR.

The lamps of this system were specially noticeable on account of the peculiar form of reflector surmounting them. Two types were shown, one

FIG. 141.

with horizontal, the other with vertical carbons. Figs. 141 and 142 show the horizontal arrangement, Fig. 141 being a general view and Fig. 142 an

FIG. 142.

enlarged view of the mechanism, in which the box A contains a coiled spring, for driving and gearing the long shaft *a a*. This shaft is divided

FIG. 143.

into two parts, connected by a clutch, and gives to the carbons a movement towards each other, by means of a bevel wheel at each end gearing into another wheel on the vertical shaft *b*, Fig. 143, which passes through

the arm carrying the carbon-holder, and has, at its lower end, another beveled wheel, gearing into a wheel on whose shaft is a friction-wheel, *e*, driving the two friction-rollers *g g*. These press on the upper side of the carbon, the under side being in contact with two other rollers, *h h*, whose pressure can be regulated by the spring and adjusting-screw, *l*. The mechanism for both carbon-holders is the same.

The clock-work is controlled by the electro-magnet *B*, whose armature,

FIG. 144.

n, is held by the spring *o*, and rests against the screw *r*. This armature controls a steer-wheel, the last of the clock-train. The electro-magnet is placed in a derived circuit, and consequently only acts when the principal

current meets with sufficient resistance to pass through this circuit. When this resistance is very small, as when the carbons are in contact or very close, a second magnet, C C, in the main circuit acts on the rod Q q, and pushes the left carbon-holder, thus increasing the distance between the carbons. At the moment of lighting, when the carbons are in contact, the magnet C C separates them, and when their distance apart is too great the magnet B brings them together again, thus regulating the arc.

The vertical lamp is shown in Fig. 144, which is similar to the one just described, except so far as changes are necessary, from placing the carbons in a vertical position. The clock-work occupies the base of the lamp, and the two electro-magnets, which in the horizontal type were at opposite ends, are brought closer together, but still act in the same way. As the carbons move on friction-pulleys, as before, this type works just the same as the preceding. It has the fault of having several large parts which will cast shadows. In both cases, as the carbons simply pass across the friction-pulleys and are acted upon by friction, their length does not affect the working of the apparatus, since they can extend beyond it as much as desired. This allows very long carbons to be used, burning all night. This seems to be the principal advantage of this lamp.

INCANDESCENT LAMPS.

LIST OF APPARATUS.

LAMPS WITH PLATINUM SPIRALS.

Moleyns' lamp.	}	De Changy's lamp.
Petrie's lamp.		Edison's lamp.

LAMPS WITH INCLOSED CARBONS.

King's lamp.	}	Bouliguine lamp.
Kohn's lamp.		Fontaine's lamp.

LAMPS WITH IMPERFECT CONTACT.

Varley lamp.	Ducretet lamp.
Reynier lamp.	Werdermann lamp—improved by Napoli.
Werdermann lamp.	Joel lamp.

LAMPS WITH CARBON FILAMENTS.

Edison system:	The Maxim lamp.
The lamps.	The Maxim regulator.
Manufacture of the lamps.	The Swan lamp.
Switches.	The Lane-Fox lamp.
Conductors.	The Lane-Fox regulator.
Junction-boxes.	
Current-regulator.	
Meters for electricity.	

LIGHTING BY INCANDESCENCE.

Before describing the principal systems shown at the Exhibition, it may be interesting to read what was known in France of the method of lighting in 1879. I therefore translate the following from *Eclairage à l'électricité*:

While, thanks to the works of MM. Gramme and Jablochkoff, lighting by the voltaic arc was considerably developed, lighting by incandescence also made rapid progress. * * * We will examine rapidly the apparatus which have been proposed to produce the electric light by using a poor conductor brought by the current nearly to the melting point.

These apparatus can be divided into three classes: 1. Lamps with metallie spirals; 2, lamps with inclosed carbons; 3, lamps with imperfect contact.

We will mention particularly in the first class the lamps of Moleyns, Petrie, Changy, and Edison; in the second class the lamps of King, Lodyguine, Kohn, Bouliguine, and Fontaine; and in the third class the lamps of Varley, Reynier, Werdermann, and Ducretet.

1. *Lamps with metallic spirals.*

MOLEYNS' LAMP.

The first document which we have found upon electrical incandescence is an English patent given in 1841 to M. Frederick de Moleyns, of Cheltenham.

The patent of M. de Moleyns relates to a new battery, to an electric lamp, and to the production of a motive force. We will only speak of the lamp.

This apparatus, which we show in Fig. 145, is composed of a globe of glass, A; of a reservoir, B, traversed by a rod, D; of two metallic packing-boxes, C C; of two platinum spirals, E, and of two binding posts for the conductors.

The tube B is slightly conical; it contains pulverized charcoal, which, in falling grain by grain upon the platinum, rendered incandescent by the

FIG. 145. — Moleyns' lamp.

passage of the electric current, gives a white light of much brilliancy; the platinum being arranged in two spirals, the circuit can be re-established from the exterior if the parts in contact should melt. All the joints are made air-tight, so that after a few minutes of working the air of the interior of the globe may no longer support combustion.

Lampe Petrie.—In 1849 M. Petrie took up again the same idea, and advised the use of iridium in the place of platinum. He explains his invention as follows:

A light can be produced by causing an electric current to pass through a short and fine conductor, which heats and becomes luminous. Since the greater number of substances melt and burn rapidly, however, I obtain a good light by using iridium or some of its alloys. The iridium can be melted sufficiently to produce an ingot when it is submitted to the heat of the voltaic arc; it is afterwards decarbonized and made more malleable;

then it is cut in small pieces, .001 meter in diameter, and from .01 to .02 meter, in length, which are fastened between two insulated metallic supports, which are in connection with the two wires of a proper galvanic battery; a beautiful light is thus obtained.

Lampe de Changy.—The 27th of February, 1858, M. Jobart, director of La Musée Industriel Belge, wrote to the Academy of Sciences at Paris that M. de Changy had just solved the problem of the divisibility of an electric current, and that he had seen with his own eyes a battery of 12 Bunsen elements produce 12 very steady lights, and entirely independent of each other. M. Jobart added that this result was obtained by means of incandescent platinum spirals, and by a regulator of the current preventing fusion.

No patent was taken in France. The only document which we have found relating to this invention is in the printed collection of Belgian patents. It is as follows:

After a work which the inventor had undertaken since 1852 upon electric lighting by means of the incandescence of imperfect conductors, and notably of platinum wire, and upon the possibility of dividing the current proceeding from a single source of generation of electricity after numerous experiments, he has obtained the proof of the possibility of this division by the use of certain arrangements, the principle of which is as follows:

An electro-magnet is placed in communication upon a principal circuit, the current is divided between the armature and the burner containing the helix of platinum wire, which is to be maintained in an incandescent state, the other part of the wire is attached beyond the platinum wire, the armature being maintained at a certain distance by a spring whose tension can be varied according to the quantity of current which it is desired to pass. The principal current by means of this device can divide itself into as many points as is desired, varying the quantity of the electricity employed at will upon one or several burners without effecting the others. For this purpose either permanent magnets may be employed which attract their armatures directly, or solenoids acting on a movable armature of soft iron.

In the case of permanent magnets they are cut in the shape of a cone, with armatures to correspond so as to establish a connection more or less great according to the play of the latter. In fine, the principle by the aid of which the division of the current is obtained, rests essentially upon the possibility of allowing the current to leap from all sides of the burner to be lit when a maximum intensity, determined in advance, has been obtained.

Edison lamp.—The experiments upon lighting by the incandescence of platinum were continued after 1858, and several electricians undertook to render it practical, but none of them succeeded in the slightest degree. It was believed to have been forever abandoned, when that famous American

item appeared which gave to Mr. Edison the honor of having completely solved the problem of the divisibility of the electric light by means of platinum spirals. We extract from Mr. Edison's patent and the summary description of his apparatus :

FIG. 146.—Edison's lamp.

Platinum and other substances which can only be melted at a very high temperature have been employed in electric lamps, but the energy of the current has soon rendered them useless. This part of the invention relates to regulating the electric current so as to prevent fusion while maintaining the substances at the temperature which renders them luminous. The regulating is obtained automatically by the heat of the conductors.

The luminous body *a* is arranged in a spiral. It is attached to the supports C C, of which one is in communication electrically with the levers S O, and the other with the plate *i* and the screw *r*. The spiral *a* is placed in a glass cylinder, *b*, which has a lid, *d*, and rests upon a base, *y*, and a pedestal, *e*; the whole is supported by a foot, *g*, surmounted by a column, *f*. It is preferable to have the light in a globe, both to retain the heat and to diminish radiation. Mr. Edison recommends either colored glass or two concentric globes containing in the annular space between them certain liquids, as sulphate quinine. It can work in the air, or a vacuum may be made in the cylinder *b*.

The electric current passed by the wire P, the post *h*, the wire *p*, the lever S, insulated from the mass *e*, the rod *x x'*, then by the wire *m*, the support C', the spiral *a*, the support C, the mass *e*, the wire *n*, the post *k*, and the wire N. The wires P and N are connected with the poles of the generator of electricity.

The double spiral *a* being the most resisting part of the circuit, it is in this part that the light is naturally developed. The rod *x x'* expands more or less according to the intensity of the current; when the heat becomes too great the expansion of the rod *x x'* causes the lever S to move, which closes the circuit at I, placing thus a part of the current in short circuit, and reducing in consequence the temperature of the spiral.

The current has no need of traversing the rod *x x'*, for the expansion of this rod can be produced by the radiation of the spiral *a*; however, it is preferable as regards the sensibility of the regulating apparatus to make use of both the direct heat of the current and of that of radiation.

In all cases the action of the short circuit weakens momentarily the current which traverses the luminous spiral, the contact *i* opening or closing alternately so as to preserve the uniformity of the light.

Mr. Edison mentions platinum, iridium, and osmium as the most suitable substances of which to make the luminous spirals.

The patent includes several curious devices: 1st, to prevent breaking the general circuit, if the spiral of one of the lamps melts; 2d, to introduce into the circuit a resistance equal to the extinguished lamp; 3d, the employment of a liquid as a regulator; 4th, the employment of a diaphragm as a regulator; 5th, for the placing in series of a great number of lights; 6th, to cause the resistance to vary proportionately to the intensity of the current, &c. But all this does not constitute an invention susceptible of immediate application, and still less of influencing a market so important as that of gas stock.

2. *Lamps with inclosed carbons.*

Lighting with inclosed carbons has been studied for a long time, but its ordinary application has met with such great difficulties that to-day it

can still be considered as of the purely scientific domain, although there already exists a certain number of apparatus working pretty well.

King's lamp.—It is to Mr. King that was granted, the 1st of November, 1845, the first patent where there was a mention of incandescent carbons.

The patent in question was actually granted in the name of King, but according to M. Giffard, the true inventor was J. W. Starr, of Cincinnati, of whom King was simply the agent.

Starr was the author of several philosophical works, and it was Peabody, the great philanthropist, who furnished him with the necessary money to carry on his experiments in England. Starr made a candelabra with twenty-six lights to symbolize the twenty-six States of the Union.

Faraday greatly admired this first experiment, at the end of which Starr and King returned to the United States. The day after their departure Starr was found dead in his bed.

The inventor in his description enters into precise details, and presents considerations which go to prove that magneto-electric machines, sufficiently powerful to produce light, already existed in 1845.

Below are translations of the principal passages of this description.

The invention rests on the employment of metallic conductors, or of continuous carbons, heated to a white heat by the passage of the electric current. The best metal for this purpose is platinum, the best carbon that of gas retorts.

When carbon is used it is necessary, on account of its affinity for oxygen at a light temperature, to protect it from the air and moisture, as shown in Figure 147.

The conductor C rests in a bath of mercury; the rod B is of porcelain; it serves to sustain the conductor C; the conductor D is fastened upon the receiver by a joint hermetically closed. The little rod of carbon A above and below, on conducting blocks, becomes incandescent by the passage of the electric current; the vacuum is previously made in the receiver, and it is best to use a barometer by placing one of

FIG. 147.

the poles of the battery in connection with the column of mercury and the other with the conductor D.

To obtain an intermittent light the circuit is broken periodically by clock-work.

The apparatus properly inclosed can be applied to submarine illumination, to the illumination of powder magazines, of mines, or to any place where there is suspicion of explosion or of rapid inflammation of very combustible bodies.

When the current is of sufficient intensity two or a greater number of lights can be placed in the same circuit, by taking care to regulate the power of the magneto-electric machines or elements of the battery producing the current.

In 1846 Greener & Staite took out a patent for a lamp analogous to that of King, showing that it would be an advantage to remove the impurities of the carbon before using it, by treating it with nitro-muriatic acid.

Lighting by incandescence, and the principle of its production had for a long time fallen into forgetfulness, when, in 1873, M. Lodyguine revived both the one and the other, and created a little lamp which served as a pretext for the formation of a stock company, which company has never brought anything to the stockholders.

In his lamp M. Lodyguine used carbons in a single piece by diminishing their section at the place of the luminous focus, and he placed two carbons in the same apparatus with a small exterior commutator to make the current pass in the second carbon when the first was used up.

The inventor stated that the only inconvenience in the use of carbon in place of platinum consists in this, that during combustion the carbon combines with the oxygen of the air and wastes away little by little, and he had guarded against this inconvenience by closing the carbon in a hermetically sealed glass. This is exactly what Starr & King had proposed and realized thirty years before him.

M. Kosloff, of St. Petersburg, who came to France in the hope of disposing of the patent of Lodyguine, improved a little the primitive lamp, without, however, arriving at anything much better.

Kohn's lamp.—In 1875 M. Kohn patented a more practical lamp, which we show in Figure 148, and which was first constructed in France by M. Duboseq. This lamp is composed of a brass base, A, upon which are placed two binding posts, N, for attaching the conductors, two brass rods, C D, and a little valve, K, only opening from within outward. A globe, B, enlarged in its upper portion, is held on the base by means of a bronze hollow screw, L, pressing on an India rubber ring exactly the same as water-gauges are arranged on steam boilers.

One of the vertical rods D is insulated from the frame and connects with a binding post, also insulated. The other rod C is formed of two parts: 1st, of a tube fastened directly to the base without insulation; and, 2d, of a small brass rod slit for part of its length; this slit gives elasticity to it and permits it to slide in the tube, while it will remain fixed if a certain effort is not exercised upon it.

The retort carbons E, to the number of five, are placed between the two small plates which crown the rods. Each carbon is held in two small blocks, also of carbon, which receive brass rods at their ends the rods are

of equal length at the lower part and of unequal length above ; a hinge, I, is articulated upon the rod C, and rests on the rod of a single carbon at a time.

If the lamp is placed in a circuit by attaching the two conductors of a battery to the binding posts N N' (the post N' is hidden by the post N, but is identical with it and is not insulated from the base), the rod of carbon E is traversed by the current which passes, by means of the hinge I to the rod F, to the two blocks of carbon O O, to the copper rod G, to the plate capping the rod D, and thence to binding M. A vacuum has been previously formed by exhausting the air through the valve K by an

FIG. 148.

FIG. 149.

air-pump, or other suitable means. The rod E reddens, whitens, and becomes luminous, its light is at first white, fixed, constant, but little by little the section diminishes, the rod breaks, and the light disappears. The hinge I then falls on another rod, and almost instantly the light is re-established.

When all the carbons are exhausted the hinge remains upon a copper rod, H, and the current is not broken, so that if there are several lamps fed by the same generator of electricity, the extinction of one does not affect the others.

To prevent the broken carbons and their blocks from falling against

the glass, M. Kohn has placed a thin copper tube in the lower part of his lamp which receives the débris until fresh carbons are put in.

Bouliguine lamp.—A Russian officer, M. Bouliguine, has combined a lamp which attains nearly the same end as that of M. Kohn with a single carbon. It is composed like the preceding, with a copper base, two vertical rods, two binding posts for taking the currents, and a valve. One of the rods is pierced throughout its length with a small hole, and has for nearly its entire length a slit permitting the passage of two little lateral ears.

The carbon is placed in this rod like the head of an ordinary porte crayon, and it is induced to rise by counter-weights fastened by means of two microscopic cords to the ears of the cross-shaped supports upon which rests the carbon.

The portion of the carbon which is to become incandescent is held between the lips of two conical blocks of retort carbon. A screw under the base allows the length of the rod which carries the upper conical block to be increased or diminished, and consequently the luminous portion is made longer or shorter. The sealing of the globe is accomplished by the lateral pressure of several rubber rings.

When the lamp is placed in a circuit, the little rod of carbon reddens and is lit until it breaks. At this moment a little mechanism,* controlled by an electro-magnet, opens the lips of the carbon holders, the counter-weight above clears out the fragments which might remain in the groove, the counter-weights below raise the carbon-rod, which enters the upper block and re-establishes the current. The mechanism, actuated by the electro-magnet, acts anew, but in an inverse manner, the carbon-holders come together, and the light is renewed.

We have several times experimented with this lamp and have never obtained very good results. It incloses too many movable pieces, and the least obstacle hinders it from working. However, we have observed that when by chance it did work regularly, the contacts were better and less numerous than those in the Kohn lamp, and it needed a less intense current for the production of a certain light.

With a Gramme machine of 100 carrels we have obtained with a single lamp as high as 80 carrels, while with a Kohn lamp we could never exceed 60 carrels.

Fontaine's lamp.—We have likewise devised an incandescent lamp which incloses a series of rods radiating to a common center, and each one carrying a carbon pencil and a central rod crowned by a circular block, in which all the carbons are fixed.

* The mechanism in question, which the small size of our engraving does not allow us to show, consists, in substance, of an iron armature placed in the interior of the lamp and of two metallic bars acting on two crossed levers articulated to the ring surrounding the carbon-holders.

By means of an electro-magnet and a small revolving mechanism placed in the foot of the lamp, as soon as one carbon is consumed the current passes to the next one, and the extinction only lasts a fraction of a second. This lamp has not been tried long enough for us to pronounce now upon its practical value.

All that we can say is that the revolving movement intended to make the current pass automatically from one carbon to the next works well, and that it is applicable to the Jablochkoff candles and to all electrical regulators.

3. *Lamps with imperfect contact.*

Varley lamp.—The lamps with imperfect contact are an entirely modern invention, and we know of no apparatus which worked with the least pretense to regularity before 1878.

The Varley lamp, which we show in Figure 150 is composed of a

FIG. 150.

carbon, *T*, mounted on a lever, *U*, and resting on a carbon block, *N*, is not practical. It is included in a patent relating to an electrical machine dated December, 1876.

Reynier lamp.—The real difficulties which beset King and all the scientists who later followed his idea, rest in the preparation of the little carbons, which, not being homogeneous, break easily and are costly, and also in the absence of a good generator of electricity.

To-day, thanks to the progress realized in dynamo-electric machines, thanks, above all, to the admirable manufacture of small artificial carbons, created by M. F. Carré, inventors have much better opportunities of producing a good apparatus.

It was while studying the question under this view that M. Reynier, already known by his regulator with circular rheophores, devised the pretty incandescent lamp which we are going to describe. M. Reynier had executed under our direction a series of experiments with some Russian lamps, similar in principle to that of M. King, and had noticed that the little pencil placed between two blocks wasted more particularly in the middle;

and that at the time of extinction the *débris* represented a notable part of the little carbon in ignition, hence a considerable loss of carbon rod. It was likewise proved by the combustion of the carbons that the light was more intense in free air than in a vacuum. These two judicious observations led M. Reynier to seek the means to utilize the pencils completely and to burn them in the air; and after a series of attempts and trials he arrived at an arrangement very well described in the note presented to the Academy of Sciences, the 13th May, 1878, by M. Le Comte du Marcel. Below is an extract.

My new electric incandescent lamp rests upon the following principle: If a thin carbon rod, pressed laterally by an elastic contact, and pushed in the direction of its axis upon a fixed contact, is traversed between these two contacts by a sufficiently energetic current, it becomes incandescent in this part and burns while diminishing at the extremity in proportion to the waste of the end; the rod, continually pushed, moves by sliding in the elastic contact so as to always rest on the fixed contact. The heat developed by the passage of the current in the rod is greatly increased by the combustion of the carbon.

FIG. 151.—Principle of the Reynier lamp.

At first M. Reynier contented himself by making a carbon rod, C, press upon a small carbon block, B, and by establishing a lateral contact, *l*, to limit the length of the incandescent portion *ij*. (See Fig. 151.) Then he connected the block B with the negative, and the contact piece *l* with the positive pole of a battery. He saw the rod cut itself into a point at *j* and burn as regularly as an ordinary candle. But he found at the same time that the impurities contained in the carbon gave rise to a residue, which rapidly interfered with the contact, and not wishing to complicate his lamp by the addition of counter-weights to change its position, he was led to replace the fixed lower contact by a movable one, as seen in the right-hand figure.

In this new arrangement the rod C rests in front of the vertical axis, upon a little wheel of carbon, B, and the tangential component of the weight of the rod rotates the wheel, and, in consequence removes the residue which insulates the point.

Starting from this last idea, M. Reynier has had a series of apparatus

made which he has successively improved and finally stopped at the combination shown in Fig. 152, which is notable for its simplicity.

FIG. 152.—Reynier lamp.

The carbon rod is fastened to the end of the upper arm or traverse, surrounding a square rod of brass. This rod slides in the interior of the lamp between four little metallic wheels. The carbon wheel is held by a collar

embracing the body of the lamp and insulated from the latter. The axis of the wheel rests on a little see-saw. The carbon is guided a little above the lower contact by a copper wheel, and the upper contact is obtained by means of a little block of carbon fastened to the extremity of an oblique rod in direct contact with the body of the lamp; the binding post to the left is used to attach the wire which leads from the positive pole of the battery or of the electric machine, and the binding post to the right connects the carbon wheel to the negative pole. The rod of carbon, pressing on the wheel, makes it turn very slowly, and as this wheel is mounted on a little see-saw, it in its turn reacts on the square brass rod, thus diminishing its motion and the part of the carbon which is ignited from breaking. The carbons are 2 millimeters in diameter and 3 meters in length; they last two hours.

We have seen this lamp work with a battery of 12 Bunsen elements, and we estimated its intensity at 15 to 20 carcel burners. The light was certainly very steady.

Some experiments with a Gramme machine and 10 Reynier lamps, made at Santter & Lemonnier's factory, gave results worthy of record.

The Gramme machine, driven by a special engine very well regulated, turned with a velocity of 920 to 930 revolutions. The resistance interpolated between the machine and the lamps was that of 100 meters of copper wire 3 millimeters in diameter. The lamps were furnished with racks and pinions. The carbon rod touched the wheel at 30° from the normal and caused it to turn by the tangential component. The lamps burnt cylindrical carbons 2 millimeters in diameter, made by Carré. The length of the incandescent part was from 5 to 6 millimeters in all the lamps; it was regulated by means of an electric contact made of a platinum wire of 2.6 millimeters with opposite contact in iron. The end contact was a wheel of retort carbon 30 millimeters in diameter, with a thickness of 10 millimeters at the centers and 4 millimeters at the circumference. Below is a *résumé* of the experiments:

No. of lamps in tension.	Indication of the galva- nometer.	Luminous in- tensity of each lamp.	Total inten- sity.
		<i>Burners.</i>	
5	25	15	75
6	22	13	78
7	20	10	70
10	15	5	50

The Serrin lamp gave, in the same circumstances, with a deviation of 21° , an intensity of 320 burners.

The lamp of M. Reynier is simple; its use is easy; its price not high—three great qualities. We are ignorant of what the future has in store for

it as regards its practical use, but hereafter its place is marked in all laboratories.

Werdermann lamp.—The Werdermann lamp, shown in Fig. 153, offers a great analogy to the preceding, as to principle. Its construction alone presents peculiarities which merit mention. This lamp is composed of a carbon disk, A, in communication with the negative pole, and of a little

FIG. 153 — Werdermann lamp

pencil, B, in communication with the positive pole of the source of electricity; of a carbon holder, C, furnished with a movable lip; of a spring, and of a screw, to assure the contact of the pencil against its inner sides; of a support, D, insulated from the body of the apparatus, and of a ring, E, serving to keep and hold the disk A in a fixed position; finally, of a counterpoise, P, acting by means of a cord and two pulleys on the pencil B to force its point constantly against the disk A. Several experiments

have already been made in England and in France with this lamp, but up to this date there is no practical installation on which we can give judgment.

Dueretet lamp.—M. Dueretet has also given much attention to lamps with imperfect contact, and he has recently presented to the Academy of Sciences different dispositions, only differing from the preceding in the manner of manufacturing the incandescent carbon. We show one of these dispositions in Fig. 154.

FIG. 154.—Dueretet lamp.

In this apparatus the incandescent carbon plunges in a mercury bath, T. A metallic cap, B, which serves to guide the carbon C, is insulated from the tube filled with mercury, either by an empty space or by the interposition of a concentric envelope in wood; it is placed in communication with the lower part of the tube by a conducting wire, t.

The metallic guides fixed on the cap B are movable, and their opening depends upon the diameter of the pencils employed.

In consequence of the repulsive action of two consecutive portions of the same current, but above all in consequence of the imperfect contact of the pencil G against the block H, which completes the circuit, a very

small arc is produced; then the pencil reddens for a certain length and is used in proportion to its combustion, constantly brought against the point H by the push of the mercury. The intense heat of the pencil is afterwards communicated to the metallic cap B, then is rapidly carried off by the metallic conductor t , which is fixed; the heat thus tends to arrive by means of the conductor t to the lower part of the tube T, but radiation renders the effect null.

This dissipation of the heat is so effectual that after an experiment of long duration the cap B became extremely hot; but the tube of iron T remained sensibly cold at its upper part where the mercury stopped. The electric current arrives directly through the mass of the apparatus to upper part of the pencils; at the same time, by derivation, the conductor t leads the current directly to the cap B; the portion of the pencil traversed by the current is thus limited by the distance comprised between the block H and the cap B, which has thus the triple effect of guiding the pencils, of facilitating the passage of the current, and of dissipating the heat which would act directly upon the mercury if the insulating envelope i were suppressed.

The conductor t' connects the bolt V (insulated from the apparatus) with the support S, also insulated from the tube T; it takes the current from the point of support H, which should be moved slightly after each time the light is used, in order to renew the surface of contact.

Of all the experimenters who have occupied themselves with light by incandescence, it is M. Changy who has made the best spiral lamp, M. Kohn the best lamp with inclosed carbons, and M. Reynier the best lamp with imperfect contact. The latter would without doubt have reached a practical solution of the problem if the problem of lighting by means of small electric arcs did not present almost insurmountable difficulties.

The objections to this system consist above all in its feeble results as compared to the motive power employed, and in the considerable expense of the installation compared to the luminous intensity obtained.

In the actual state of things, with the generators of electricity now in use and the apparatus proposed to utilize electricity, we do not believe that light by incandescence will be generally adopted; circumstances may occur where its application will be interesting and even useful, but in order that it may be developed it is necessary that a gas motor of low price be invented or that thermo-electric batteries become really practical.

In the meanwhile, one can recommend incandescent lamps, that of M. Reynier especially, for laboratories and manufactories which have already powerful electrical apparatus, and which can without inconvenience insert in the circuit one or several lamps with imperfect contact.

INCANDESCENT LAMPS AT THE EXHIBITION.

The systems of lighting by incandescence are much less numerous than those by the voltaic arc; their classification is also much less complex. They may be divided as follows;

1. Lamps incandescent with combustion.
2. Lamps purely incandescent.

The former class is represented by the apparatus of Reynier, Werdermann, and Joel. They are all composed of a carbon pencil, resting lightly upon a carbon or metallic block, and thus producing an imperfect contact.

The second class is represented by four systems, Edison, Maxim, Swan, and Lane-Fox. All these lamps depend upon the incandescence of carbon. This carbon consists of a very fine filament placed in a vacuum, or in very rarified atmosphere of inert or vivifying gas.

The nature of the current is nearly a matter of indifference as regards incandescent lamps; they work with continuous or alternating currents. Those with combustion require a high E. M. F. and are mounted in *tension*, while those purely incandescent require a low E. M. F. and are mounted generally in *quantity*.

FIRST CLASS.

LAMPS INCANDESCENT WITH COMBUSTION.

REYNIER.

M. Émile Reynier exhibited a collection of his various lamps, showing their development, also a collection of metallized carbon rods for his lamps.

This lamp has already been described, and, as those exhibited do not differ in principle, and but little in detail, a further description is unnecessary.

WERDERMANN.

The Werdermann lamp has also been described, but it has been so much changed and improved—thanks to the labor and ingenuity of M. Napoli—that its present forms should be described. It was represented by a number of lights. In one of the upper galleries was a dining-room, handsomely furnished, with the table laid for dessert, lit by a central Werdermann lamp, and several others were in other parts of the room. The small theater was also lit by this system, six lights furnishing the footlights, and a handsome chandelier, with twelve lights, lighting the auditorium.

The advantages of an incandescent over an arc light are the divisibility of the light, its color, and its constancy. The latter advantages can only be obtained when the waste of the carbon is perfectly regular. Now, the

waste is made the greatest at the end of the carbon pencil by making it rest against a block of graphite; the contact being necessarily imperfect at this point, the resistance becomes more considerable there than elsewhere; as the temperature rises and the waste of the carbon becomes more rapid, the pencil thus burns away to a point.

It was necessary to have recourse to this artifice of using a block, else the carbon pencil would have burnt for its whole length, and could not have been continually renewed, and it would have been impossible to have obtained a

FIG. 155.—Werdermann lamp, Napoli system.

light capable of shining for some hours. But from the moment that the carbon was caused to rest against the block, by a point very fine and necessa-

rily fragile, it was necessary to take precautions to cause it to descend regularly—for, if at any time it should break, the resistance of the incandescent part of the circuit would suddenly vary, and, consequently, the light also. A brake was therefore devised, which only allowed the carbon to advance, little by little, in proportion to the waste of the point.

In the earlier lamps the two jaws of the vise, which constituted the brake, wore out, on account of the perpetual friction of the carbon, but especially on account of the intense heat to which they were subjected; it followed that their exterior edges finally touched and that the carbon no longer remained in actual contact; in consequence, the brake no longer acted and it rendered possible an accident which might render the apparatus useless; that is to say, the establishing of a voltaic arc between the carbon and one of the jaws.

Different methods have been devised by M. Napoli to prevent this, varying according to the uses to which the lamp may be put.

First arrangement: The movement from below, upward, of the carbon is obtained by a system of weights, cords, and pulleys, identical to that employed in the Werdermann apparatus; also, the upper end of the carbon presses against a round block of graphite, but first it passes through two holes in the upper part of two little cupolas in copper, D, D', having the form of a bell of a clock. One of them, of a smaller diameter at the base, penetrates concentrically in part and can there move freely in a small angle. Moreover, these little cupolas can turn in opposite directions around each other, on an axis perpendicular to that of the carbon rod. Their action can best be compared to the action of a pair of scissors upon a rod which one wishes to cut; no matter how worn may be the blades, they can always press the rod strongly, without ever coming in contact.

As soon as the upper point of the carbon rod is consumed, the graphite wheel falls by its own weight and causes, by means of the levers L, L', a slight movement of rotation of the cupolas around their axis; the latter separate, and allows the carbon to ascend a short distance, which at the same time raises the graphite block; at this moment the levers are actuated by the latter and retake their original position, thus again grasping the carbon.

It will readily be seen that these new jaws can be used indefinitely, as they never can touch each other.

Second arrangement.

This arrangement is simpler than the former and casts less shadow. The carbon rod passes between two metallic wheels, O and O', whose thickness is less than the diameter of the rod; hence, whatever may be the wear of these wheels, they can never come in contact. The figure shows plainly

how the holding-power of these two wheels is a function of the position of the graphite block.

FIG. 156.

Third arrangement.

In this the carbon rod descends instead of rising, and the graphite block is fixed; the metallic wheels have been replaced by segments, whose edge is also less than the diameter of the carbon rod; one is fixed, the other presses against the rod, owing to the counterpoise.

To prevent the carbon from descending too rapidly under the influence of the weight, a spring is interposed between the upper end of the carbon and the weight; the weight is given a cylindrical form, with a diameter slightly less than the interior of the tube, and its surface is furnished with a series of circular grooves.

Other arrangements differ but little from the preceding; one has a device for closing the circuit, in case the carbon is exhausted, so that other lights in the same circuit will not be extinguished; another shows how two or more lights may be placed in the same globe.

The inventor states that the diameter of the carbon is $4\frac{1}{2}$ millimeters,

the consumption per hour 10 centimeters, the light equal to 40 carcel burners, and the motive force expended 38 kilogrammeters.

The light is good, but has its disadvantages; although quite steady, it occasionally varies slightly, when the point of the carbon breaks. This may be remedied by more careful manufacture of the carbon. Another disadvantage is that the lamp, presenting little resistance, requires currents of great quantity; consequently, the conducting-wires have to be of large diameter. It works equally well with continuous or alternating currents.

JOEL LAMP.

The Joel lamp may be called a modification of the preceding, and looks like a Werdermann lamp turned upside down. There are several essential differences, however. The negative element is of bell metal, while that of the Werdermann is a plate of carbon or coke.

The Joel lamp consists of a vertical pencil of carbon, forming the positive electrode, 5 millimeters in diameter, resting on its lower point upon the middle of a block of bell-metal, which is connected with the negative terminal of the machine. There is a simple and ingenious arrangement for releasing the clips or jaws by which the carbon pencil is held and dropping it on the lower electrode as soon as its point is so far burnt away as to cause a separation between the electrodes, and also for short-circuiting the lamp the moment the current is interrupted. There is also a simple arrangement by which the opening of the case of one lamp in a series short-circuits that particular lamp, so that others are not affected by its extinction during the process of putting in fresh carbons, or of any other adjustment. One of the rooms in the upper gallery is illuminated by six of these lamps, which form part of a circuit of ten, the other four being at the driving station—the generator employed being one of the new up-right form of the Siemens direct current machine.

This lamp was not very successful. A Frenchman writes: "The ten incandescent Joel lamps which illuminate (?) this hall produce the effect of mortuary candles lighting the great show-cases of the retrospective museum." If this is an allusion to the antiquities which fill this hall, the local color is in truth only too well observed.

SECOND CLASS.

LAMPS PURELY INCANDESCENT.

EDISON SYSTEM.

Edison's first system of lighting by incandescence made use of an incandescent platinum wire, but in practice it was not satisfactory, principally on account of the disintegration and partial fusion of the wire; and although he succeeded, by an ingenious process, in making it much more

infusible and much harder, it finally had to be thrown aside, at least as far as the usual style of lamp was concerned. Then King, Lodyguine, Bou-liguine, Swan, Sawyer, and others attempted to use carbon, which, when it does not burn, is infusible at the highest temperatures developed in the lamps. Some attempted to avoid combustion by placing the carbon in a vacuum, others by filling the globes with gases which would not support combustion.

To say the most, all of these experiments were but moderately successful, and when, in 1879, Edison announced his new lamp with incandescent carbon, it met with tardy belief. This horseshoe of carbonized paper appeared incapable of resisting mechanical shocks, or of supporting, for any length of time, the incandescent action.

Edison continued to improve his lamp in many ways, and, finally, his perfected lamp is as now shown at the exhibition.

When completed, these lamps are sufficiently strong and will last a long

FIG. 157.

FIG. 158.

FIG. 159.

time. The carbon, which at first was fragile, has become extremely rigid and so fine that it can be compared to a horse-hair. The platinum wires, which conduct the current to the carbons, are ingeniously fastened to them and they are so sealed in the glass that their change of volume will not affect the vacuum. The bubbles of air in the pores of the carbon are removed before the closing of the lamp, by heating the carbon to incandes-

cence, while the vacuum is being produced. This also renders the carbons extremely dense and hard.

These carbons are not made of paper but of filaments of bamboo, which are carbonized by a special process. The resistance of these filaments, corresponding to an incandescence of 16 candles, is 125 ohms; but this can be varied at will, according to the luminous intensity required.

Fig. 157 shows the completed lamp; their life is about one thousand two hundred hours; they cost, to replace, about 30 cents per lamp, and a new lamp can be substituted for a broken one in a few seconds.

But it is not only the lamps which constitute the Edison system; every detail has been thought out and is here shown, from the machine for generating the electricity to the button for lighting and extinguishing the lamp.

The form of the Edison lamp will be understood by reference to Figs. 157 and 158, the former being a 16-candle lamp with a resistance of 140 ohms, the latter an 8-candle lamp of half that resistance. In Fig. 157, the two ends of the carbon filament are connected, respectively, by a screw and a cone, each stamped in thin brass, held at a proper distance apart and insulated from each other by a filling of plaster of paris. The socket into which this fitting screws, and which is in permanent connection with the main conductor, consists of a cone of thin brass, below which is a hollow screw, both being embedded in a mass of plaster of paris and forming a counterpart of the fitting on the lamp.

This form has certain disadvantages, however, one of which is that the action of the mechanical contrivance is to put a tensile strain on the plaster filling, and, therefore, tends to break the connection, by pulling the screw and cone apart. This has been corrected in the form shown in Fig. 158, in which the upper cone has been removed and a flat disk or sole plate, shown at the bottom of the figure, has been substituted for it. When a lamp of this form is screwed into its socket, the sole plate is pressed against a corresponding plate at the bottom, and the strain on the plaster being one of compression, there is no tendency for it to be pulled apart. The lamps have been still further improved by substituting thin copper instead of brass and changing the pear-shaped globes into a form consisting of a cylinder with hemispherical ends, Fig. 159. By this arrangement, the sides of the element are at a more uniform distance from the incandescent filament; they are, therefore, less liable to crack and there is less loss of light through refraction and internal reflection.

Without going into the details of construction of the lamp, the various operations will be understood by referring to Figs. 160 and 161, the former showing the various processes for making the globe and inserting the carbon filament and wires—the latter showing the different shapes given to the bamboo.

After the bamboo filaments have been carbonized and placed in the globes, the globes are attached to a Sprengel pump, and, while exhaustion

FIG. 160.

FIG. 161.

is going on, the filaments are alternately heated and cooled by the passage of an electric current; this confers upon them their homogeneous and

FIG. 162.

elastic character, as well as their refractory nature, at high degrees of temperature, which are so essential to a good incandescent lamp.

Fig. 162 shows a jointed wall bracket, carrying one of these lamps, the interesting feature being the construction of the joints on which the arms of the bracket are pivoted.

Fig. 163 shows a view of the joint A, and Fig. 164 that of B. It will

FIG. 163.

FIG. 164.

be seen that the two conducting wires, connected with the main circuit, are connected respectively to two metallic springs, which press against two brass collars insulated from one another, and which are in connection with the insulated wires that pass through the tubular arm of the bracket to the lamp.

The electricity is turned on or off by a similar action to that used for

FIG. 165

FIG. 166.

gas. When the button, shown under the letter A, Fig. 162, is turned, it makes or breaks contact, by lowering or raising the conical plug, shown in Fig. 165. The plug consists of a split cone with a strong spring,

keeping the two portions apart, thus insuring a firm contact, when the cone is drawn into its seat between the two plates.

To complete the description of the Edison system, it will be necessary to mention the conductors, by which the electricity is distributed over a district to be lighted, from a central station; the switches and other details connected with the distribution; the apparatus for regulating the strength of the current, and the instruments by which the extent of the current utilized or lost is indicated and recorded.

The conductors are of three classes, viz: (1) The principal and sub-mains, which carry the main current under the streets; (2) the cables employed for derivations for house service; (3) the single insulated wires of various diameters, by which the groups of lamps are placed in circuit with the service conductors and their branches.

Those of the first class, or electric mains, alone require especial notice, the two other classes having no material differences from the cables and wires used in other systems.

The conducting portion of the mains consists of two solid copper rods of segmental cross-section, Fig. 166, the figure showing cross-sections of three different sizes, suitable respectively for large mains, for branch circuits, and for mains of smaller installations.

FIG. 167.

The two segmental bars are protected from injury and from moisture by being passed through the middle of a wrought-iron pipe, and are held in position, in the first place, by diaphragms punched out of stout mill-board, threaded on the rods at intervals, and the intervening spaces an

then filled with a bituminous compound, which performs the three functions of keeping the conductors in the middle of the tube, of insulating and protecting them from damp, and of so completely filling the tube that the latter, with its conductors in place, can be bent to any desired angle without distortion of its sectional cross-figure or displacement of its contents. Specimens of these conductors, of various sizes, and in lengths of 15 to 25 feet, were exhibited.

As copper rods of such length must necessarily expand and contract considerably, under the influence of change of temperature, they would distort the mains and injure their conductivity and insulation, unless some provision were made to meet this difficulty, which is provided for, as shown in Fig. 167, which is an illustration of a main junction box, with its cover removed. It consists of a box of cast iron, H H, with double walls, through the sides of which pass the ends of two pairs of conductors, X Y and X' Y', to be joined; the connection between them is made by two horseshoe or U-shaped strips of copper, A B, which, on account of its form, can close or open as the straight conductors elongate or contract. This box also shows how the branch submain *x y* is connected with the main circuit, the conductor *x* being connected to the loop A by the copper strip D, while *y* is connected to B by the bent strip C.

Every branch circuit throughout the system is, moreover, protected

FIG. 168.

against any sudden increase in the strength of the current by being provided with a safety-guard, consisting of a short length of lead wire, through which the whole of the current, passing into a branch circuit, is transmitted. So long as the current is of its normal strength it acts simply as one portion of the conductor, but its cross-section is so determined that it is incapable of transmitting a current of a strength above that at which the branch circuit can be worked with safety; the moment this limit is reached

the lead wire fuses and the branch to which it is fitted is cut out of the circuit. This arrangement is shown in Fig. 168, representing a junction-box for connecting the cables, for a house-service with a submain. In this case the conductors of the two submains are coupled together by the curved copper rods A, B, C, D, and the house-cables X and Y enter the box by the tubes shown on the top of the figure, being connected, respectively, with the blocks G and H, the former of which is coupled to C and D by the short piece of lead wire E, which, by fusing, should the strength of the current exceed a certain limit, cuts out the branch without affecting the main current.

In nearly all electric light systems, especially in those in which currents of great quantity and low electro-motive force are employed, considerable trouble is experienced by the burning and consequent destruction of the contact surfaces of the switches.

In the switches adopted in the Edison system, especially in those used for interrupting strong currents, this difficulty is much reduced; first, by dividing the spark over two, three, or more interruptors at the same moment; second, by increasing the area of the surfaces in contact, and, third, by insuring extremely rapid making and breaking of the circuit. Fig. 169 is a view of the back of a threefold switch, showing the interior. This switch is so designed that by turning the cross-handle M M, through a portion of a revolution, the three conical plugs E, F, and G, which are

FIG. 169.

nearly identical in construction with that shown in Fig. 165, are simultaneously thrown in or out of their seats, which are cut in the edges of the four plates A, B, C, and D. The current, entering by the attachment-screw H, passes in succession through D, G, A, E, B, F, and C to the other terminal-screw K, and as this is accomplished by a cam suddenly setting into action a strong spring the interruption is extremely rapid, and the sparking is distributed over no less than six surfaces, so that not only is

FIG. 170

the spark much reduced but the area of the surface contact is much increased.

The strength of the current is regulated to the work it is required to do by varying the resistance of the exciting circuit of the field magnets so as to proportion the intensity of the magnetic field to the current required for feeding the lamp circuits; the mechanical resistance to the rotation of the armature is varied accordingly, and with it the motive power for driving the machines.

The current regulator, Fig. 170, consists of a rectangular table, supporting beneath it a number of coils of German silver wire wound upon skeleton bobbins, between which, and between the convolutions of each helix there is a free circulation of air, so as to keep the whole system cool. All these coils are coupled together in series, the first being connected to one attachment-screw of the apparatus, the other attachment-screw being connected to the regulating lever, which, by being moved over a number of contact-pieces arranged in a circle on the upper table, and connected, sever-

FIG. 171.

ally, with the resistance-coils underneath, can be made to throw into the circuit of the field magnets of the generator or generators any number of the resistance-coils.

In permanent installations the regulating-room is provided with photometers, by which the photometric value of one lamp, in any circuit, can

continually be observed, and there is also an indicator of the electro-motive force, consisting of a reflecting galvanometer, the resistance of the circuits being so balanced that, when the indicating spot of light rests at the center of its scale, the current is normal; but the spot moves to the left or right, according as the electro-motive force diminishes or increases. In addition, there is an apparatus for measuring and recording the quantity of electricity transmitted from the central station into the electric mains, for utilization in the various circuits, as well as one for indicating the quantity of current that has been used by any one consumer.

FIG. 172.

The principle of both instruments depends upon the fact, that the weight of metal deposited per unit of time, in an electro-plating bath, is proportioned to the quantity of electricity passing through it in the same period, or, in other words, to the strength of the current; and, as the amount of this electro-deposition is equal at all points of a circuit, it follows, that by placing an electrolytic cell in any part of a circuit, the amount of electricity transmitted by the cell in a given time can be determined by observing the quantity of metal deposited within the same period. The apparatus is shown in Figs. 171 and 172.

The house meter consists, generally, of two electrolytic cells, so connected as to form together a shunt to the lighting current, and, also, so arranged that one cell is capable of transmitting a greater quantity of electricity than the other, the proportion between them, however, remaining the same.

The two cells are fitted into a small cast-iron cabinet, as shown in Fig. 171, and below them is a simple, automatic arrangement, to be hereafter described, for preventing the temperature of the cells from falling below a certain degree.

In the earlier form of meters, the electrolyte employed was a solution of sulphate of copper, the electrodes being of pure copper; but, in the more recent instruments, the copper solution has been replaced by a solution of sulphate of zinc, and the electrodes are of zinc, by which arrangement the polarization currents are much reduced and the accuracy of the results increased.

Referring to Fig. 172 V and V' , are the two glass cells, each of which is filled with a solution of sulphate of zinc, in which is immersed a pair of amalgamated zinc plates. The two cells are precisely alike, but, from the fact that one cell is short-circuited by a shunt having one-fourth the resistance of the shunt by which the other is short-circuited, the quantity of electricity passing through the former, per unit of time, is four times that which is transmitted by the other, and, therefore, within a given period, the quantity of metallic zinc deposited on the receiving-plate of the one cell is four times that which is deposited on that of the other. The short-circuiting shunts are shown at R , and consist of a corrugated band of German silver, of which the twelve on the left constitute the shunt of the cell V , while the remaining four belong to the right-hand cell V' . L is an ordinary incandescent lamp, which is thrown into circuit whenever contact is made at the point A , and this is effected by the bending downwards of the compound expansion-bar AB , which is so constructed and adjusted as to automatically throw the lamp into circuit whenever the temperature within the instrument falls below a certain point.

The radiant heat from the lamp then raises the temperature of the air within the apparatus, until by the upward bending of the compound bar the lamp is again cut out of the circuit; r r' are two compensating resistance-coils, which are included in the branch circuit of the cells, their object being to keep the resistance of the apparatus uniform, under variations of temperature; for, as the resistance of the zinc solution is diminished by a rise of temperature, the quantity of electricity transmitted by it would be greater as the temperature was increased, unless this increase were compensated or neutralized. To effect this, a coil of copper wire is inserted in the circuit of each cell, and, as the electrical resistance of copper increases with a rise of temperature, while that of the zinc solution diminishes, it is only necessary to make the length of the copper wire such that its resistance rises in proportion as that of its corresponding cell diminishes, in order to compensate the apparatus for variations in temperature.

The method by which the various parts of the apparatus are coupled

up, will be understood by reference to the diagram, Fig. 173, which also shows the position of a lamp-circuit, with respect to the meter.

The zinc plates are shown in detail, in Fig. 174; they are 3 inches long, 1 inch wide, and $\frac{1}{4}$ inch thick, fixed at a distance of .24 of an inch, by placing two little ebonite blocks of that thickness between the plates, and fastening the whole together by an ebonite screw, passing through the middle of the plates; before being put together, however, a coating of chemically pure zinc is deposited by electrolysis, upon the surface of each

FIG. 173.

FIG. 174.

plate, and the plates afterward amalgamated with pure mercury; this reduces the local action to a minimum.

The most interesting and elaborate apparatus of this kind is the automatic meter or electric counter, represented in Fig. 175, and which is best suited for the laboratory or central station, for it might easily be put out of order in unskillful hands.

The apparatus consists of two electrolytic cells, each containing a solution of sulphate of copper, and in each of them is immersed a hollow cylinder of copper; within this cylinder is suspended, from the end of the beam of a sensitive balance, another copper cylinder; the two cylinders in each cell constitute the electrodes of an electro-depositing bath, and according as to whether the current traversing the cell is in one direction or the other, so will the metallic copper be transferred from the fixed to the suspended cylinder, or *vice versa*, and the connections are so made, that while the apparatus is depositing copper on the inner cylinder of the one cell, metal is being dissolved from the inner cylinder of the other cell; thus, while the one is, during the passage of the current, becoming heavier, the other is losing weight. It is clear from this construction that a time must come when the one will overbalance the other, and the beam will, in consequence, be deflected; in doing this the current is automatically reversed, and traversing the cells in the opposite direction the process is reversed, copper

being dissolved from the heavier suspended cylinder, while the other is receiving a deposition in the other cell, until it overbalances the first, causing the beam to be depressed, and, again reversing the current, sets the instrument to its original position; the process thus being repeated as long as the current passes.

FIG. 175.

Connected to the beam by suitable mechanism is an ordinary counter, by which the number of oscillations of the beam is recorded, and, as each oscillation represents the deposit of a certain weight of copper, and that weight is a measure of the quantity of electricity throwing through the instrument, the current is measured mechanically by a method very similar to that of a gas-meter.

The apparatus has an electro-magnet attachment, by which the instrument can be so adjusted that the very slightest motion of the beam to one side or the other of a certain fixed point makes an electrical contact, thereby throwing one or the other of the electro-magnets into circuit, and, by the attraction of an armature, causes the beam to fall over.

Considerable prominence has been given to the Edison system of incandescent lighting, as the inventor has worked out all its details in a most

ingenious and original manner, and has perfected a complete system, in which all the various parts have been wrought out carefully and are in harmony with each other.

THE MAXIM LAMP.

To form the filament of the Maxim lamp, a piece of bristol-board is first cut in the shape of the letter M, with rounded angles ; it is then slightly carbonized and placed in a glass globe filled with the vapor of gasoline ; the current is then passed through the filament and the gasoline is decomposed, depositing carbon on the filament. As the thinnest part of the fila-

FIG. 176—The Maxim incandescent lamp.

ment will be the most highly heated by the current, the most carbon will be deposited at that point, and the filament will become homogeneous ; this process is continued until the resistance has been decreased to from 40 to 60 ohms ; a vacuum is then produced until the pressure does not exceed .00001 of an atmosphere ; the slight portion of vapor remaining will act as a renovator should any one part of the filament remain thinner than another.

The two ends of the filament are prolonged by two platinum wires, which are soldered to the glass globe by means of a kind of bluish cement, resembling enamel, in the mass of which the wires are introduced, and, as

this cement attaches itself strongly to the glass, there is no danger of affecting the vacuum by the contraction or dilation of the wires.

The inventor states that these lights are each of 26 candle-power; that six of them can be maintained per 1 horse-power, and that their duration is from six hundred to nine hundred hours.

An ingenious switch attached to each lamp lights or extinguishes it at will. The lamps are so made that they can be placed in their supports or removed from them with as much ease as a candle. The lamps are all placed in derived circuits; each is perfectly independent of the others. At London they were placed in ordinary gas brackets, the gas-pipe serving to carry the return current. The main cable is composed of nineteen copper wires 1.6 millimeters in diameter; to this cable those of less size are attached, and the diameter of the wires is gradually reduced to .85 of a millimeter, which supplies 6 lights, the wire of each light being .3 of a millimeter in diameter. In case of a sudden increase of the current, this last-mentioned wire will fuse before the platinum of the lamp, which will, therefore, not be injured.

THE MAXIM CURRENT REGULATOR.

The regulator of the intensity of the current is placed on the top of the machine for exciting the field of force of the dynamo, and is intended to regulate, automatically, the current furnished by the latter. This is accomplished as follows: A magnet, wound with fine wire, placed in a derived circuit and seen at the top of the regulator, attracts, with a force varying with the strength of the current, an armature, to which is suspended a catch with two opposite teeth, which has a to and fro motion, owing to the way in which it is hung. This catch moves between two toothed wheels, which it does not touch when the current is normal. Should the current diminish on account of putting additional lamps in in the circuit, the armature, being less strongly attracted, will recede from the magnet, being lifted by the little spring shown at the left, and will raise the catch, whose upper tooth will engage in the tooth of the upper wheel, which in consequence will turn a certain distance.

By means of suitable gearing this motion is transmitted to the collecting brushes of the armature of the exciter, which are arranged so as to turn around, so that they can approach or recede from the maximum and neutral points. When the brushes approach the maximum points the intensity of the current of the exciter is increased, and thus the intensity of the induced current from the dynamo is also increased. If, on the contrary, the current is too intense, owing to some of the lights having been extinguished, an opposite action will cause the brushes to approach

the neutral point, and the current will be correspondingly reduced until the normal is reached.

FIG. 177.—The Maxim current regulator and exciter. Elevation.

A second pair of magnets, placed alongside the first, have their armatures so regulated by a tension-spring that they will only move when the current is considerably increased, which might happen if one of the main

cables were broken. In this case a prolongation of the armature comes in contact with a platinum point and shunts the magnetic field of the exciter, thus stopping the production of electricity until the break has been repaired.

FIG. 178.—The Maxim current regulator and exciter

THE SWAN LAMP.

The Swan lamp consists of a glass globe, in which are introduced two platinum wires, split at their ends, so as to form jaws, and in which is

held the carbon filament, the necessary pressure being obtained by two little sliding rings (see Fig. 179); the contact is made by two contact springs.

FIG. 179.

FIG. 180.—Hand-lamp, with Swan light.

The carbon conductor is formed from cotton thread (the most suitable being that known as crochet thread), which has been subjected to the action of sulphuric acid, in the proportion of two parts of acid to one of water, so as to cause a change to take place, according to the well-known process of making vegetable parchment. After a sufficient time to effect the change, the thread is removed from the solution and washed with water until the whole of the acid is eliminated, after which it is dried and placed in a

crucible filled with charcoal dust, which is hermetically sealed and heated to a white heat for a certain time. The filament is now placed in a lamp, the vacuum obtained by a Sprengel pump, and the filament is brought to incandescence by means of the electric current, which removes all the gas from the pores. This last operation lasts for half an hour; the filament has now become much harder, denser, and thinner. Its resistance varies from 30 to 100 ohms, and the light from it, according to Mr. Swan, from 12 to 25 candles.

In order to avoid the heating effects, where the platinum wires enter the globe, these wires are surrounded by glass tubes for nearly their whole length. The arrangement for a hand-lamp is shown in Fig. 180. Contact is made and broken by simply turning the handle at the right of the figure.

Mr. Swan has used both storage batteries and dynamo machines for furnishing the necessary electricity.

When machines of high electro-motive force are used the lamps should be mounted in tension; on the contrary, when the machines are for furnishing electricity in quantity, the lamps should be placed in derived circuits, in order to obtain the best results.

THE LANE-FOX LAMP.

This lamp resembles those already described; but the carbon filament is made of a different material and fastened to the wires in a different way.

FIG. 181.—The Lane-Fox lamp.

The filament is made of a stalk of "dog's-tooth" grass, or of threads made of vulcanized vegetable fibers impregnated with oxychloride of zinc. By carefully carbonizing these stalks or threads, then placing them in a vacuum and heating them to incandescence, they become hard and strong, the same as in the other systems. The ends of the filament are inserted into

a little plumbago cylinder, the platinum conductors being inserted into the other end; these wires are cemented into a glass globe with two branches, these branches having enlargements, *e e*, near their ends, which are filled with mercury; the upper part, where the wires leave the globe, is filled with tightly-packed cotton and closed with plaster of paris, *g'*. A later form substitutes spirals of platinum, *e e*, for the plumbago, to which the filaments are cemented with Indian or Chinese ink, and marine glue, *g*, takes the place of the cotton packing.

The platinum wires are not continuons, but their ends dip into the mercury, which forms the electrical connection between them; the device is

FIG. 182.—The Lane-Fox regulator.

intended to allow for expansion and contraction, without affecting the vacuum, which is obtained by a barometer, so arranged that the vapor of mercury is eliminated. The globes are generally of ground glass and are hung in a polished copper shade, which forms a reflector.

It is stated that it requires 2 horse-power to supply electricity for 15 lamps, each furnishing a 12-candle light; their resistance varies from 75 to 105 ohms, when cold.

The regulator of the intensity of the current consists of an electro-magnetic vibrator, *G E*, analogous to that used in electric bells, which turns a ratchet-wheel, *N*, whose axis carries a geared pinion placed between two other wheels, *R R'*, having a common axis. This axis carries at its extremity an arm, *F F*, moving across the arc, *e e*, connected with regularly

increasing resistances, so that, as the wheels $R R'$ are turned in one or the other direction, a larger or smaller resistance is introduced into the circuit. The axis of these two wheels has a longitudinal motion and is acted upon by an electro-magnetic system, consisting of two electro-magnets, $E' E'$, having a common armature, A , and a kind of relay E'' , with double contact, I , which sends through the two electro-magnets $E' E'$ a local current strong enough to make the pinion engage one or the other of the wheels $R R'$. As this relay is placed in a derived circuit, it can react upon the resistance of the circuit, by means of the arm, $F F$, which will then re-establish the initial intensity.

The lamps are always mounted in a derived circuit, and, at the Exhibition, the Brush machines were used to supply the electricity.

NOTE.—Since the above was written Mr. St. George Laue-Fox delivered a lecture before the Royal United Service Institution, giving additional details of his system and other interesting information. It is reprinted in Ordnance Notes No. 249, February 17, 1883.

LIGHT-HOUSES.

As a more connected and better idea of the use of electric light in light-houses can be obtained by giving a history of its use in France than by describing isolated exhibits, this has been done.

The lamps, lenses, and generators mentioned in this history were shown at the Exhibition, and the most prominent object in the Palais de l'Industrie was a light-house in the center of the building lit by electricity and having a revolving light with alternate red and white flashes.

HISTORY OF THE APPLICATION OF THE ELECTRIC LIGHT TO LIGHTING
THE COASTS OF FRANCE.

The value to navigation of thoroughly lighting our coasts is too evident to require any argument in its favor; and, in view of the immense interests at stake, there is no question but that improved methods of lighting should be adopted, almost regardless of expense, providing that the advantages gained are in any way commensurate with the cost.

France has long appreciated this; and it is to her that the world owes the Fresnel lens and many improved lamps burning successively whale, vegetable, and mineral oils. She has finally led the way, as usual, in the use of the electric light, which has been definitely adopted for the lighting of her coasts, after many expensive and conclusive experiments; and, when the plan has been fully carried out, France can boast of having the best and most systematic method of coast-lighting of any country in the world.

The United States has followed France. Our optical apparatus has been almost exclusively imported from that country. We use lamps made after French patterns, and now are about to make experiments to determine the value of the electric light for use in our light-houses. This is deemed sufficient excuse for giving full details of the French system. The information has naturally been mostly obtained from French sources.

It was in 1863 that the electric light was for the first time used in light-houses. The experiment was made with an Alliance machine in the first-order light-house of La Hève, near Havre; and the results were so satisfactory that doubtless all the light-houses would have been immediately furnished with electric lights, had it not been for the great expense attending a general alteration. It was proved that the electric light was seen about 8 kilometers farther than the oil light, and that in time of fog the range of the former light was more than double that of the latter.

M. Quinette de Rochemont, ingénieur des ponts et chaussées, published in 1870 a report upon the light-houses at La Hève. Below are some extracts :

The electric light having been installed for six years at La Hève, enough time has elapsed to allow us to form an exact idea of the value of this means of producing light for the lighting of coasts. Sailors take pleasure in recognizing the good services rendered them by the electric light. The advantages of the system have been highly appreciated; the increase of the range of the light is very apparent; and, above all, in slightly foggy weather many ships can continue their voyage, and enter the port at night, which they could not do when oil was used. The light, which at first was rather unsteady, gradually acquired a remarkable fixity, thanks to the improvement of the apparatus and to the experience gained by the keepers. The fears which were at first entertained regarding the delicacy of certain parts of the apparatus are not realized in practice. The accidents have been rare, the extinctions short and very few, two only during this period of six years having had a notable duration; one, of an hour, was due to an accident to the steam-engine; the other, of four hours, should, it appears, be attributed to malevolence. Under these circumstances it seems hardly worth while to worry about possible accidents.

Since 1863 experience has only confirmed the favorable views of M. Quinette. The light-houses of Gris-Nez, France; Cape Lizard, England; Odessa, Russia; and Port Said, Egypt, have been provided with electric apparatus, and there is a question of placing it in the light-houses of Planier and Palmyre, France, and in several light-houses in other foreign countries.

The following information was furnished by MM. Sautter and Lemonnier :

When the light is to be fixed, the optical part of the apparatus is composed of a lenticular drum of proper form, which renders the rays horizontal in the vertical plane while allowing them to diverge in the horizontal plane. The dimensions of this drum vary from a diameter of half a meter for a fourth-order light to one meter in a first-order light. This increase in diameter of the apparatus is sensibly proportional to the increase in diameter of the carbon pencils between which the voltage is produced, and which determines very nearly the dimensions of the electric light. It follows from this that the vertical divergence remains the same in the different types of apparatus. When the light is to be revolving, the fixed lens is surrounded by a movable drum formed of straight vertical lenses, of which the form varies according to the characteristics desired to be given to the light.

Revolving electric lights have this great advantage over revolving oil lights: the flashes can be given a duration equal to that of the eclipses. In oil lights, when the light is concentrated in the form of flashes, there are two ends in view: First, to augment the intensity, and consequently the range of the light; second, to create an appearance different from that of a fixed light. The first can only be obtained by giving *the flash a duration much shorter than that of the eclipse*; or, in other terms, by making the angle of the luminous beam a small part of the angle subtended by the lens. Moreover, this angle depends on the di-

mensions of the *foyer*,* and it can only be augmented either by increasing this dimension or by changing the focal distance of the lens, thus losing a part of the light, since the divergence is produced not only in the horizontal plane, the only one in which it is utilized for prolonging the flashes, but in every direction. With the combination of vertical lenses and a cylindrical drum, which serves to produce flashes when electricity is used, the divergence of the beams can, by giving the vertical lenses a proper curvature, be augmented as much as desired in the horizontal plane, and the duration of the eclipses be diminished in proportion, while the range of the smallest electric light used will nevertheless remain much greater than that of the most powerful oil light.

For example: The luminous intensity of an annular panel of 45° of a first-order revolving light with a six-wick lamp equals 9,847 carcels. This is the greatest intensity obtained with an oil lamp. The divergence of the beam given by this same panel is $7^\circ 7'$, and the duration of the flash is about one-sixth part of the eclipse which precedes and follows it.

By applying the methods of M. Allard to the photometric measurements of electric lights it is found that the luminous intensity of a fourth-order electric light, with a lens half a meter in diameter, and fed by a small-model Gramme machine, equals at least 20,000 carcels; and when concentrated by means of straight movable lenses in beams having a divergence such that the durations of the eclipses and flashes shall be the same, its intensity will be equal to 40,000 carcels; that is to say, that it will be four times more intense than that of the most powerful oil lamp, and with a much shorter duration of eclipse.

By means of electricity such immense quantities of light are produced that it is not necessary to take into account more or less beams in order to augment the range, the only object of the movable lenses being to produce characteristic appearances which distinguish clearly each light-house from its neighbor. These characteristic appearances, the method for producing them, and the system now adopted in France, will be mentioned farther on.

The different lights which serve for the lighting of French coasts are designed so as to answer the different needs of navigation; and their importance varies in consequence according to the rôle they are called upon to play, of which the most important is that of signaling to navigators their approach to land; and the lights constructed for this end are placed in preference upon more or less advanced headlands, which form, according to the expression of M. L. Reynaud, "the angles of a polygon cir-

* The French word *foyer* means literally a *hearth*, a *place where something is burnt*, and, in the sense used here, *the source of light and heat*, the *space occupied by the flame of a lamp or by the electric arc*. The word is so useful that I take the liberty of using it in place of an English paraphrase.

circumscribing all dangers." These are the lights which should have the greatest luminous power, and which, therefore, constitute *first-order lights*.

Between these extreme points indicating the general contour of the coast the latter still presents advanced points, which should become centers of lights of less importance and serve to guide the vessels to their harbors. The secondary lights placed on these points are called *second-order lights*, and merit their name, not only by their position, but also on account of the less power given to their optical apparatus. Along the route thus traced for navigation are also found localities which it is important should be pointed out to sailors; these are, for example, sand-banks, sunken rocks, islets, &c. From these arises the necessity of luminous *foyers* of various intensities, and the creation of *third, fourth, and fifth order*, and of even less powerful *lights*, such as are placed in harbors on the end of jetties, to show vessels the entrance to the channel.

In addition, among all the lights of different orders, some, placed on an island, are designed to throw their light entirely around them; others, built on an advanced promontory, or established on a straight part of the coast, only send their rays on a fraction, more or less great, of the zone which surrounds them; finally, others only have to light a determined point; hence the distinction of lights in *lights of all the horizon, of three-fourths the horizon, of two-thirds the horizon, &c.*

Until 1863 all the lights of the French coasts were furnished with apparatus for oil; and it was not until this epoch that there was installed, at one of the two lights of La Hève, the first apparatus for lighting by electricity. After a year and a half of experiment, the result having been most satisfactory, it was decided to light in the same way the second light of La Hève; and, about two years later, the electric light was also placed in the light-house at Cape Gris-Nez. Matters remained in this condition until within the last few years; and while England counted on her coast six electric lights, the three which we have just mentioned were the only ones in existence in France. Lately, the reconstruction of the light-house of Planier having been adjudged necessary, it was decided to use the electric light in it; and the same decision was taken regarding the light-house of La Palmyre, whose luminous intensity was recognized as insufficient.

But the good results given by the electric light at La Hève and at Cape Gris-Nez called attention to the more general service it could render; and on the 27th January, 1880, after a long study of the question, M. Allard, director of the French light-house department, presented to the minister of public works an important report, recommending the general adoption, upon the whole extent of the French coasts, of electric lighting. This report was approved on the 4th December, 1880, by the conseil-général des ponts et chaussées; and the principle of electric lighting has just been

adopted for the entire extent of the coast. This decision was so important that it seems proper to mention here the principal points of M. Allard's report, to make known the arguments brought to the support of using the electric light, and the results obtained in various trials, and, finally, to give details of the electric installations of this nature actually in use.

Before mentioning the considerations in favor of changing oil for electricity, we must speak a few words on the range of light-houses. The *range* is the distance to which the light is visible at sea; the *circle* of range has this distance as a radius, and the light as a center. The range of a light depends not only upon the optical conditions in which the light is placed, but also upon its height above the level of the sea. Thus there is a distinction between the *geographical range* and the *luminous range*; the latter being the one under consideration. It increases with the transparency of the atmosphere, which is very variable, and changes with the locality; thus, on an average, it is much greater on the Mediterranean than on the southwestern coasts of France, greater on the latter than on the shores of Brittany, and becomes the least in the British Channel. Moreover, the transparency varies according to the seasons; and there are during the year a certain number of more or less foggy days, during which the transparency of the air and the range of the light are both diminished. It is impossible, therefore, to fix the range as a certain quantity; and it is necessary to establish a mode of designating the varying range. To do this, observations are made during the year on the variations of the range; the foggiest nights are then omitted, and the minimum range for the remainder of the year represents the range for that portion of the year. If, for example, thirty nights, or one-twelfth of the year, are deducted, and during the remainder of the year the smallest range is 12 nautical miles, it is considered that the light under consideration has a range of 12 miles for eleven-twelfths of the year. In short, the range of a light during a portion of a year is the distance at which it is always visible during that portion.

In order that the lighting of coasts be efficient, it should be continuous, so that a vessel sailing along the coast, as soon as it passes the range of one light, should come within that of the next; in other words, the *circles* of range should cut each other successively. With the system of oil lights now in use this is actually the case, but only during half the year; during the other half the oil lamps have not sufficient power. It will be very different when the electric light is used. The ranges will be increased, and the circles of ranges will cut each other during eleven-twelfths of the year.

The accompanying outline map, Fig. 183, shows what would be the ranges if the electric lights were used, supposing that each light had a

mean intensity of 125,000 carcels. The dotted lines show the present ranges with oil lamps. When the electric light is adopted, the range of the new lights will be 27.7 nautical miles in the Mediterranean for fourteen-fifteenths of the year, 19 to 21 miles in the British Channel for ten-twelfths of the year, and 22 to 26.5 miles on the Atlantic coast for the same period.

If the increase in the range, by using the electric light, is a powerful consideration in favor of this system, objections may, however, be made on the score of economy. The report of M. Allard shows that the expense of executing the entire programme, even including the installations of steam-sirens, will not exceed \$1,600,000, which is very reasonable compared with the results obtained. Besides, the cost of maintenance of electric lights is not, as one might have supposed, much greater than that for oil lights. Thus the annual expense of a first-order oil light is about \$1,660 per year, while for each electric light-house at La Hève the cost is \$2,270, and for that of Gape Gris-Nez \$2,680. If it is desired to compare the cost of a unit of light for a light-house lighted by oil with one lighted by electricity, it is found that the former costs \$81 per unit, while the latter is \$22 at Cape Gris-Nez, and \$19.40 at La Hève.

It should be said here that there is only taken account of, in the above figures, the light of the *foyer* itself, independently of the optical apparatus, which, by concentrating the rays, augments the intensity very considerably.

The number of electric lights comprised in the project is forty-six, counting as two the double lights of La Hève, of La Cauche, and of Hourtin. Of this number there are thirty-eight of the first order, two of the second order, five of the third order, and a new one to be placed at the south of Paimpol. Four of these lights are already, or are about to be, lighted electrically.

As to the distribution of the lights, it is easy to follow it upon the map (Fig. 183). Almost everywhere the circles of ranges cut each other, and where there is a gap it will be filled with an oil light. This map also gives the distinctive characteristics of the different lights, and this is a most important point to be considered.

In a good system of coast-lights, the neighboring lights should have very distinctive characteristics, in order to avoid all possible confusion. In the existing system, these conditions obtain, and the first idea which naturally presented itself was to retain the old characteristics, simply substituting the electric for the oil light, so that there would be no change from that to which sailors were accustomed; but the existing characteristics are, in some ways, inconvenient, and it has been decided to replace them by others, which, by making the lights more easy to be distinguished, will, besides, increase the range.

FIG. 183.

The present characteristics are as follows :

1. A single fixed light.
2. A double fixed light.
3. An eclipsed light, with flashes every half minute.
4. An eclipsed light, with flashes every minute.
5. A fixed light varied by flashes every four minutes.
6. A fixed light varied by red flashes every four minutes.
7. A light with alternate red and white flashes.

Fixed lights are obtained with a Fresnel apparatus with cylindrical lenses; the double fixed light, by two lights situated at such a distance that they can easily be distinguished from each other, but still appear to form a pair. Fixed lights will eventually disappear, because they have a less range than flashing lights, and also are liable to be confounded with other fixed lights not belonging to a system of coast-lighting.

Flashing lights are obtained by means of optical apparatus having generally eight faces. Each face comprises, first, a lense of the same width as the face, then, above and below, portions of rings having as a common center the center of the lens. The apparatus thus gives rise to eight beams of light, separated by dark intervals, and when it is turned the navigator sees alternately a flash and an eclipse. The intervals between the flashes depend upon the rapidity of rotation. This light has the inconvenience of requiring sustained attention and the consulting of a time-piece to tell the length of the interval. It should be suppressed.

The fixed lights varied by flashes are obtained by means of an apparatus for a fixed light around which turn two or three vertical lenses which give flashes, either white or red, or alternately white or red, at intervals of some minutes. These slowly revolving lights have the same fault as the preceding, and will also eventually disappear.

The characteristic which will be generally adopted is that of a *scintillating* light. To produce it, a fixed-light apparatus is employed, around which revolves a drum of lenses, placed vertically, composed of straight glass bars of lenticular cross-sections; each of these concentrates the horizontal rays, and consequently produces a flash. During a rotation, if all the lenses are alike, the navigator will see a series of equal white flashes, producing a scintillating light. If the vertical lenses are alternately red and white, there will be alternately a red and a white flash, and a compound red and white scintillating light will result. In the same way, by placing the lenses in groups, there can be two, three, four, or more white flashes, followed by a red one. It should be remarked that, in this case, as the red color diminishes the luminous intensity, the red lens should have larger dimensions to compensate for this loss; as this causes a loss of light, M. Allard prefers, in most cases, to separate the group of white flashes simply by an obscure interval. This is obtained by a simple modi-

fication in the form of the vertical lenses. There are thus the following eight characteristics :

1. White scintillating light.
2. Light with alternate red and white flashes.
3. Light with two white flashes and one red successively.
4. Light with three white flashes and one red successively.
5. Light with four white flashes and one red successively.
6. Light with two white flashes, with intervals of obscurity.
7. Light with three white flashes, with intervals of obscurity.
8. Light with four white flashes, with intervals of obscurity.

These are the only characteristics which have been definitely adopted. They have the advantage of being readily recognized without consulting a time-piece.

The Serrin regulator, arranged for alternating currents, has been adopted as the standard lamp. No other apparatus has given better results. Especially with alternating currents, its working is excellent, because the armature of the electro-magnet detaches itself very easily ; and besides, as the consumption of both carbons is uniform, the arc remains absolutely fixed.

The machines for generating the current have been of late years the subject of attentive study, which has been unfortunately confined to three types, the Alliance, Gramme, and De Meritens. The luminous intensities of each of these machines, have been measured under carefully arranged conditions. Photometric measurements in such cases are rather delicate. To make them, since the intensity varies in the vertical direction with different heights, a movable mirror is used, which is placed at different heights, in the same vertical plane, and which, in each position, throws the rays on the photometer ; and thus the average intensities could be obtained. But, as the intensity of the electric light constantly varies, it was necessary to make the observations at one-minute intervals for each position of the mirror. It is not necessary here to go into the details of construction of the different machines ; the table below gives the results obtained.

Machines.	Number of revolutions per minute.	Horse-power.		Luminous intensity	
		Total.	Loss power used in transmission	Total	Per horse-power.
				<i>Candle.</i>	<i>Candle.</i>
Alliance	450	5.18	4.02	275	56.4
Gramme No. 1	550	12.04	11.48	1819	66.2
Gramme No. 2	600	6.01	5.45	409	36.7
Gramme No. 3	600	7.06	4.20	342	32.4
De Meritens	700	8.06	7.50	526	34.4

It will be seen that the Alliance machine gives a far less intensity per horse-power than the two others, which are approximately equal. The De Meritens has certain characteristics of stability and solidity which the Gramme machine does not possess; it was, besides, preferred to use alternating currents. For these reasons it has been adopted, and will be installed in all the new light-houses.

The figures giving the intensity in the preceding table refer to the naked light. When this is placed in a fixed-light apparatus, these intensities become, in round numbers, 12,000 careels with the Alliance, and 20,000 careels with the Gramme No. 2. The flashes increase the intensity still more. In a scintillating light with red and white flashes there is an intensity of 60,000 careels with the Alliance, and 110,000 careels with the Gramme machine; with a scintillating light with groups of white flashes, 90,000 careels for the former, and 150,000 careels with the latter. The intensities with the De Meritens machine are about the same as with the

FIG. 184.

Gramme; and 125,000 careels may be taken as the average intensity when the electric light is used.

Some details will now be given of the installations actually existing and of those in process of construction, especially describing the lights of La Hève, the first in date to be electrically lighted, and the Planier light, whose installation has just been completed.

The lights of La Hève, situated on the cape of this name and on the top of the cliff, are, from this fact, very elevated; so the towers themselves are not of great height. Both towers are square, and are placed about 60

meters apart, between them being the long building containing the steam-power, generators, and quarters for the keeper.

There are four Alliance machines, two for each light. The two on the left supply the left-hand tower, and the two on the right the tower on the right hand. The conductors leading the current from the generator are, first, thick copper rods connected with the commutator, Fig. 184. The rod A communicates with the two similar poles of the two machines, the rods B and B' being connected to the opposite poles. Ordinarily one machine supplies each light. Thus the current arrives by A, and, without traversing the commutator, goes by the cable to the regulator (or lamp); thence it returns by the second wire of the same cable to N, follows the vertical conductor to P, and returns to the machine by the rod B. If it is desired to use the machine corresponding to the rod B', the central handle is turned, thus bringing the plate D in contact with P' instead of

FIG. 185.

P, retaining always the contact at N. In this case the current arrives, as before, at A, goes to the regulator, returns again, but passes this time from N to P', and thence to the machine by B'.

In foul weather, or whenever it is necessary to increase the luminous intensity, both machines are coupled in quantity. The commutator is then turned until the plates E and E' are in contact—the one with P'

and N' , the other with P and N , the return current flowing simultaneously by B and B' .

The tower of each light is surmounted by a square structure, at one of the angles of which is the optical apparatus. This is clearly shown in Fig. 185. A kind of glass drum closes the open angle of this structure, which is in two stories, in each of which is a distinct optical apparatus. The intention of this arrangement is to allow one optical apparatus to be instantly replaced by the other, in order to avoid total extinction in case of accident. In each story there are two regulators, which can be substituted for each other by means of the crossed rails shown in Fig. 186. The cable with three conductors leading from the commutator, previously

FIG. 186.

described, arrives at the lower story. One of the conductors (A) is connected to the metal platform carrying the rails, also metallic; the conductor B connects with the sliding rod of the long bolt $M T$. When this bolt is lowered it connects the conductor B with a wire going from the bottom staple of the bolt to a spring contact under the lamp. The latter receives the current, partly by the rails, partly by the contact underneath. The wire B communicates with a smaller bolt sliding at the same time with $M T$, and whose lower staple is connected to the wire coming from the staple of the larger bolt, so that when the current passes by B' it always traverses the lamp, and when the two machines are at work together the two currents are united by the connection between the two staples. The upper

staples are connected in the same way to the apparatus in the second story, and when the bolts are raised the upper lamp is lighted.

The regulators can thus be changed in two ways, either by drawing the lamp at work back on the rails and quickly pushing the other one in its place, or by manipulating the commutator bolt, which shifts the luminous are from one story to the other. Since the establishment of the lights at La Hève the latter means have been found superfluous, and will no longer be employed.

The light of Planier, which has just been finished, is about 8 nautical miles from the port of Marseilles, upon a rock. It is a tower 60 meters high, and 18 meters in diameter at the base, which rests on the rock itself.

FIG. 187.

Fig. 187 gives the details of the summit of the tower, and Fig 188 those of the optical apparatus. In the latter figure are shown the fixed-light apparatus, and, movable around it, the drum, with vertical lenses.

The mechanism for driving the latter is given in considerable detail.

In this apparatus the changing of the regulators is effected by means of a system of two pairs of rails; but they are not placed at an acute angle, as at La Hève. One enters direct into the optical apparatus; the other is placed outside, and at right angles to the first. At their junction is a

turn-table, and, with this arrangement, the maneuver of changing the lamps takes no longer than with oblique rails.

The De Meritens machines, which feed the regulator, are placed in a special building. The plan and elevation of this building, which will serve as a type for those installed at most of the light-houses, is shown in Fig. 189.

The Planier is a full horizon light. Its characteristic is that of three

FIG. 188.

white flashes separated by a red flash. Its range, like that of all the new lights in the Mediterranean, is 27 nautical miles for fourteen-fifteenths of the year.

We have mentioned that the transformation of the Palmyre light is also in progress. This, unlike the Planier, will throw a beam in one direction only; and the arrangement of the lantern is therefore slightly different.

It is shown in Fig. 190. The general disposition resembles, up to a certain point, that of La Hève. The optical apparatus for the new fixed lights will have a diameter of 0.6 meter, instead of 0.3, as was formerly employed. With the revolving cylinder of vertical lenses this diameter will reach 0.7 meter.

As the electric installation at the Planier light-house is the newest and most complete, some further details of its arrangement will be of interest. The plan (Fig. 189) shows clearly the position of the two generators and of the transmission-shafting which sets them in motion.

Both generators are placed upon the same masonry foundation, and

FIG. 189.—A. Engine and boiler house. S. Electric generator room. F. Forge and heavy repair shop. d. Shop for light repairs. D. Coal depot, with water-tank underneath. c. Water-tank. V. Vestibule.

their axes are in the same line. In order, however, that one may be ready to replace the other in case of accident, their shafts are keyed together, and they both turn, the one with an open, the other with a closed circuit. Between the two machines is a short column (shown in Figs. 191 and 192), which supports the guides for changing the belts from the loose to the fixed pulleys.

Each machine is divided into two circuits, shown by four terminals placed at the upper part of the frame, two at each end. The two terminals placed beside each other at each end of the machine are those which at a given instant form poles of the same name. From each of them is

led a copper conductor to the foot of the machine ; thence, along the masonry foundation, it follows along the ground (as shown in Figs. 191 and 192), and arrives at a commutator placed on the masonry column, which

FIG. 190.

forms one support of the shafting. One object of the commutator is to take the current at will from either machine ; another is to couple, either in tension or quantity, the two circuits of each machine. The four possible combinations of the commutator are shown in Fig. 193. An examination of this figure shows that the apparatus consists of fixed and movable contacts arranged in a circle. The first are fourteen in number. The

four on the left are in relation with the terminals 1, 2, 3, 4, from which are led the conductors of the machine on the left, or machine No. 1. The four on the right are connected with the terminals corresponding with the conductors of machine No. 2. The three upper contact pieces are attached to the terminals communicating with the conductors of the lamp.

It should be said that the current reaches the lamp by a large cable, then, after traversing the arc, is divided between two smaller cables, in one

FIG. 191.

of which is placed the electro-magnet of the lamp. Of the three upper contacts, that of the left communicates with the terminal E, to which is connected the cable of the electro-magnet just mentioned; the next belongs to the terminal P C, of the second small cable; finally, the right contact,

FIG. 192.

twice as large as the others, is in communication with terminal G C, of the large cable. This system of fixed contacts is completed below by three pieces, the center one having double the length of the others. The side

pieces communicate by means of auxiliary conductors—that on the left with the contact piece of the terminal E, that on the right with the contact piece of the terminal G C.

The movable contacts to the number of eight are shown in the figure. They are all carried on one plate, free to move around the center of the apparatus. The two innermost contacts are connected together so as to form a sort of $\cap$; the next pair forms a larger $\cup$; and the four others are connected, two and two, by circular strips. The different pairs of contacts are, of course, insulated from each other. A handle in the center of the movable plate serves to place it in different positions.

FIG. 193.

Suppose, for example, that the movable contacts are in the first position shown in the figure for quantity. The terminals 1 and 2 being at the same instant poles of the same name, the current enters simultaneously by the two movable contacts corresponding to these terminals, and passes at the same time into the small cable and the cable in which is the electromagnet. After passing the carbons, it is reunited in one conductor, and returns by the large cable to the terminal G C. On the fixed contact of double size, in connection with this terminal, rest the two movable contacts by which the current returns to the terminals 3 and 4.

In coupling for tension in the same machine, the current, leaving the first circuit of the machine by the terminal 1, traverses the most open pair

of movable contacts, and arrives at one of the lower fixed contacts by means of the conductor auxiliary to the contact G C. It then follows the large cable, passes through the carbons, and only traverses the small cable of the electro-magnet to arrive at the terminal E; thence, by the second auxiliary conductor, to the smallest pair of movable contacts and terminal 4. It then traverses the second circuit of the machine, and returns to the terminal 3. Afterwards, by the second pair of movable contacts, it arrives at the large, lower, fixed contact, from which it is conducted by the third pair of movable contacts to the terminal 2; that is to say, to the first circuit of the machine.

In examining the positions of the movable contacts shown for coupling machine No. 2 for tension or quantity, it will be seen that the direction of the currents is similar.

FIG. 194.

Fig. 194 gives a perspective view of this commutator. The contacts are covered with an ebonite plate, through which passes the handle for manipulating the movable plate. This ebonite plate bears four inscriptions, corresponding to the different combinations of the commutator; and an index moving with the handle indicates the combination in use.

The system has the advantage of changing instantly the grouping of the two circuits of the same machine, and of quickly substituting one machine for the other. It has, however, the drawback, common to all turning-contacts, of not being absolutely reliable.

In the English light-houses, for which the De Meritens machine has also been adopted, another style of commutator is used, as shown in Fig. 195. In this arrangement, the terminals to which the conductors from the lamp and

those from the two machines are connected have practically the same relative positions as in the previous case. From these terminals pass stout copper strips, which can be clamped by binding-screws bearing the same numbers as the terminals. The locking-pieces in connection with the terminals of the machine can be connected by thick copper strips by the binding-screws cor-

FIG. 195.

responding to the lamp-cables ; and to facilitate this coupling, the locking-pieces are more or less raised, so that the strips may cross each other without touching. In this way perfect contacts are obtained ; but a longer time is required to change the combinations. Fig. 195 shows the connections when machine No. 2 is coupled for quantity. Fig. 196 allows the difference in height of the locking-pieces to be seen, and shows how machine No. 1 is coupled for quantity.

The metallie rails upon which the regulator rests have already been described. These rails are in direct communication with the large cable ; and it is by them that the current arrives at the frame of the regulator, and thence reaches the carbons. The cable of the electro-magnet and the small cable are attached to two terminals (H and H, Fig. 197) with insulated springs. These springs, pressing on two contacts under the lamp, make the appropriate connections.

The regulator itself is a combination of the Serrin and Berjot lamps. It comprises the two electro-magnets of the latter lamp, the armatures of

which form an internal core, one magnet having coarse wire, and placed direct in the circuit; the other having fine wire, and mounted in a derived current. The former acts on the articulated frame carrying the lower carbon; the latter acts on the disk brake controlling the clock-work.

Fig. 197 shows at S the electro-magnet with coarse wire acting by the arm Q on the frame. R and R' are the springs which tend to raise this frame. L is the lever which serves to regulate the tension of the spring R; it is controlled by a screw, V, which can be turned by inserting a key at the hole O. The magnet with fine wire is placed symmetrically with the other on the opposite side of the clock-work.

FIG. 196.

The connection of the two carbons to the prime mover of the clock is made by means of a steel ribbon, F, attached to the lower ends of the two rods *g* and *l*. This ribbon is led over several pulleys, and is wound around on a wheel on the axis of the prime mover for a great part of its circumference. The turning of this wheel is thus produced in a very

certain manner. The rod *g* slides in the tube *D* fastened to the movable frame, and this tube is slit vertically to allow the attachment of the ribbon to pass. This manner of connecting the two carbons, which replaces the chain used by Serrin, and does away with the use of ratchet-wheels, allows the carbons to be placed at any desired height by a slight sliding of the ribbon.

Another peculiarity of this lamp is the mode of connecting the dif-

FIG. 197.

ferent interior parts of the apparatus. The current of large cable arrives at the upper carbons by the rails and uninsulated portions of the regulator. From the lower carbon it returns to the two insulated terminals *H* and *H'*, passing to one by the movable frame, and to the other through the

electro-magnet S. The connections between the contacts are made with four thick spirals of nickle-plated copper. Two are shown at M and N.

The tube D, which carries the rod *g*, is not insulated from the frame; but the latter is insulated from the upright which supports it. This is on account of ease of construction, it being less difficult to insulate a straight piece than a round tube like D. An air-pump, T, serves to check the motions of the frame, and to prevent too rapid oscillations. The porous plate V is placed opposite the ends of the carbons, to protect the rods *t* and *l* from the excessive heat of the *foyer*. It is composed of the same material as the porous vases used in batteries. When the upper carbon rod arrives at the end of its course it acts on a beveled piece, which frees a contact-spring, and suppresses the communication with the fine wire magnet, so that it may not be injured by the passage of too strong a current.

It only remains now to describe the De Meritens machine to complete the description of the electric appliances for light-houses.

M. De Meritens has devised several types of machines. The one adapted for light-house purposes, shown in Fig. 198, has the permanent

FIG. 198.

magnetic horseshoe form arranged radially around the axis in a precisely similar manner to the disposition of the field-magnets of the old Alliance machine, which in general appearance it at first sight much resembles.

Fig. 199 is a transverse section of the machine, and Fig. 200 a longitudinal section taken through the axis, so as to show, in both views, the armature-ring and the position of the field-magnets with respect to it.

Figs. 201, 202, and 203 show the details of the armature-bobbins, marked *H*, the iron core-pieces *h h*, and the projecting pole-pieces, which form enlarged ends to the latter, and are marked *g*. In Fig. 201, which represents a section through half the ring, the method of attachment and of coupling up is clearly shown. On reference to Fig. 199, it will be seen that each armature-ring, *G*, is built up of sixteen flattened oval bobbins, *H*, separated from one another by the projecting pole-pieces *g*; and around each ring are fixed, radially to the frame of the ma-

FIG. 199.

chine, eight very powerful compound permanent magnets, each composed of eight laminæ of steel. The distance apart of the two limbs of each magnet, as well as the distance between the north pole of one magnet and the south pole of the next, is precisely equal to the distance apart, or pitch around the armature, of the pole-pieces and the coils. The details of the magnets, and their method of adjustment and attachment, are shown in Figs. 204 and 205. Each magnet is built up of eight laminæ of steel, each ten millimeters in thickness, and held together tightly by the bolts and nuts *c d*, the whole being attached to the brass frames *F*, which are fixed to the framing of the machine in radial slides, by which the distance from the armature-ring can be adjusted with great accuracy. The total weight of the forty magnets (see Fig. 198) is about one ton.

The currents from the five armatures are brought together in two groups, to the four brass collecting-disks *i*, which are mounted in pairs on an insulated bush, *j*, fixed to the principal shaft of the machine. The details of the collecting apparatus are shown in Figs. 206, 207, and 208. Against

the disks *i* are pressed, by means of springs, the four collecting plates or brushes *K' K'*, which are in metallic connection with the attachment screws *K K*, of which there are two pairs, one at each end of the machine (as shown in Fig. 200).

FIG. 200.

The construction of the armature is very interesting and ingenious. Each of the induction-coils shown at *H* (Figs. 201, 202, and 203), is composed, first, of a flat spool or bobbin of the form marked *h*, and then is wound in a lathe with insulated copper wire 1.9 millimeters in diam-

FIG. 201.

FIG. 202.

FIG. 203.

eter, and of which the total weight in the whole machine is from 120 to 130 pounds. The iron cores of these coils are built up of eighty thicknesses of soft sheet-iron 1 millimeter in thickness, and stamped out by a machine. The coils are wound, and attached to the armature wheel by a set of bolts, marked *e*, which pass through the projecting lugs *g* of the wheel, and through the cylindrical hole formed by the semi-cylindrical

grooves in the ends of the iron core-pieces when abutting the one against the other.

The coupling-up of the armature coils is one of the most ingenious features of the machine; for, as the magnets are arranged around the armature in such a way that in the rotation of the coils alternate poles

FIG. 204.

are presented to any one bobbin, it follows that if the bobbins were numbered 1, 2, 3, 4, &c., up to 16 the currents induced in all the even-num-

FIG. 205.

bered bobbins would be in one direction and in all the odd numbers in the opposite; and it would appear at first sight that these coils could not

FIG. 206.

FIG. 207.

FIG. 208.

be connected together in series without the one set of currents neutralizing the other. But by connecting the armature coils together in the man-

FIG. 209.

ner shown in Fig. 209 it will be seen that although the currents generated in consecutive coils are opposite in direction to one another, yet their combined current transmitted to the collecting apparatus is in the same direction.

In the early part of this article attention was drawn to the distinction between the luminous and geographical ranges; and in all the installations described regard has only been paid to the increase of the former, the latter being neglected. This is readily explained by the necessity there was of giving a unit to the new system of lighting the French coasts. There is, however, a point which it will be important to consider, and which may serve to augment the efficiency of the system. In days of heavy fog, when the luminous range is considerably diminished, this diminution would be much less if the geographical range could be increased.

A rather important step has been made in this direction by the use of specially-constructed optical apparatus. This apparatus is furnished on the upper part with a series of annular lenses, whose effect is to project above the light a beam of vertical rays extending to a great height. This beam illumines either the clouds, or the vapor which fills the atmosphere, and is even visible in clear weather, because the air contains enough particles, both solid and vaporous, to allow the phenomenon of diffusion to be produced. These luminous rays thus projected are visible to quite a distance even in foggy nights, and the geographical range is notably increased.

The first application of this system, which has not yet been adopted in France, is about to be made in the Sea of Azof. The ships which cross this sea in the direction of Berdiansk are guided to their point of arrival by a light, which, in the actual state of its installation, could not be seen sufficiently far, and it was decided to apply the system mentioned above. The apparatus recently constructed by Messrs. Sautter and Lemonnier will shortly be installed, and then the efficacy of the system can be judged.

The example thus given by the French light-house board has already been followed by other nations. The Ottoman Government has studied a plan of electric lighting for the coasts of Turkey. In England an appropriation has been asked to establish, in 1881, about sixty electric lights, and a similar request will be made for the establishment of a hundred lights in 1882.

On account of the time which the complete execution of the project for lighting the French coasts will take, it may be that the experience obtained with the first lights will show some modifications to be made in the adopted plan, and that the lights last made may not have entirely the same dimensions and characteristics as those first built.

In fact, some criticisms have been made by foreign engineers, especially on the diameter of 0.6 meter of the optical apparatus, a diameter which these engineers consider relatively too small. The faults ascribed to optical apparatus of small diameter are those of heating too readily on account

of the proximity of the luminous *foyer*, and also that of being more quickly covered with carbon-dust. We do not, however, believe that there is much to fear from this with apparatus 0.6 meter in diameter, since for the last twenty years the lights of La Hève have worked well with apparatus 0.3 meter in diameter. The probabilities are that the future modifications will only be changes in detail, which will not affect the general project.

The above shows the means France has taken to light her coasts, and is a most emphatic recognition of the value of the electric light for that purpose.

The arc light, however, has two defects which have not been mentioned—one, a lack of fixity, the other a deficiency in the red and yellow rays of the spectrum. This lack of fixity is partly due to the carbons not being homogeneous, and partly to faults in the regulators. Improved processes of manufacture have in a great measure removed these defects, but even the best lights will still occasionally flicker.

The red and yellow rays have the greatest penetrating power; and for this reason an oil light, which is rich in these rays, can be seen farther in foggy weather than an electric light of *equal candle-power*; but the electric light can be made so much more powerful than the best oil light that this deficiency can be more than made up; still, it must be borne in mind when the candle-powers of the two lights are compared.

When the French system was adopted, the incandescence electric light had not left the domain of experiment, and even now its luminous intensity is very much less than that which can readily be obtained from an arc light of moderate dimensions. It possesses, however, the element of remarkable fixity, and is rich in red and yellow rays. No light could be better for a light-house, if it can be produced cheaply, have sufficient luminous intensity, and be made reliable. It will, moreover, dispense with the somewhat complicated and expensive regulators.

It is in this line that the Light-House Board of the United States is about to make experiments, and the results obtained will have great interest for the whole world.

Since writing the above the Light-House Board has contracted for an iron skeleton tower 250 feet high, carrying six powerful arc lights, to be erected at Hallet's Point, New York, by November 1, 1883, for the purpose of illuminating the passage through the Hell Gate. It is expected that this light will be in operation during the summer of 1884.

This will be the first application in the United States, by the Government, of the electric light as an aid to navigation, and will not be a light-house in the ordinary sense of the term, but is intended to light the channel in the same way as electric-light towers light the streets of various cities, notably in Cleveland, Ohio, and at Madison Square, New York,

where the Brush Company has erected towers 250 and 150 feet high, respectively, for that purpose.

The Light-House Board has also ordered the necessary lenses and electrical appliances for the purpose of testing the value of both the arc and incandescent lights for light-house purposes. The experiments will be made at the light-house depot, Staten Island, under the immediate charge of the district officers.

REFLECTORS FOR THE ELECTRIC LIGHT.

M. Balestrieri, an Italian professor, has devised a style of reflector, which might be used as part of a light-house system in certain cases where

FIG. 210.

a very powerful light would not be required, and where a beam of light would only be needed in one direction. It possesses the advantages of ease and cheapness of manufacture. Its feature, instead of attempting to

create curved surfaces, is to break these surfaces into elements and to replace each of these elements by a simple surface having approximately the same powers of reflection.

The system is thus composed of successive bands which the inventor

FIG. 211.

calls fillets (*armilles*). They can be used as collectors or reflectors, according as they are placed in front of or behind the light. The principle is

FIG. 212.

readily seen by Fig. 210, which is a section of a collector. The figure has been constructed by taking the luminous point O as a center; but this is not necessary, as it may be placed in front of this point, as shown in Fig. 211.

When it is desired to apply the principle to a reflecting apparatus, it may be constructed as shown in Figs. 212 or 213, the latter being the best, as it embraces a larger angle for the same amount of material.

FIG. 213.—Balestrieri's reflecting apparatus.

In the collectors, the conic surfaces are made of plates of silver-plated metal mounted on a light frame. In reflectors, in order to gain strength,

FIG. 214.

the cones are made of a continuous surface. The two styles are shown in Figs. 214 and 215.

The system admits of various modifications. The reflecting surfaces might be generated by revolving Fig. 210 around a vertical instead of a

FIG. 215.

horizontal axis. The beam may be diffused at pleasure, by changing the angle of the reflecting surfaces.

Only conical surfaces are used, as these can be developed; they can be readily made by cutting the *armilles* from a flat sheet and then curving them; they are also easy to repair, in case of accident, and ought not to be costly to construct.

Experiments made by Professor Tyndall showed that this apparatus was equal, if not superior, to a lens such as is used in light-houses, the same lamp being used with each. Experiments made in Paris in 1878 also gave good results. Experiments made at Staten Island did not confirm the above; it was there found that the lens was one-third better than this apparatus. A grave objection would be the difficulty of keeping the metal surfaces brilliantly polished. Lenses can be kept in good order with much less trouble.

MILITARY TELEGRAPHS.

LIST OF APPARATUS.

Siemens alphabetical telegraph.

| Siemens magneto-electric dial instrument.

Messrs. Siemens Brothers exhibited an alphabetical telegraph apparatus and magneto-electric dial instrument, well adapted for military purposes; the former is shown in Fig. 216.

FIG. 216.—Siemens Brothers alphabetical telegraph and polarized alarm.

The large circular case, Fig. 216, with horizontal dial and handle, for the transmission of messages, contains the steel magnets and mechanism for the generation of the electric current, and is called the “transmitter.”

The smaller case above, with dial and pointer, contains the mechanism for indicating the effect of the electric current transmitted, by turning the handle of the transmitter, and is called the "indicator."

The transmission is performed by simply lifting the handle of the transmitter and turning it sharply from left to right to the letter to be telegraphed, resting there a moment, then turning to the next letter required, and so on until the word is spelled. The letter dial of the transmitter is bordered by a metallic ring, with as many incisions or notches as there are divisions in the letter circle. These incisions serve for the handle to fall into as soon as the manipulator arrives with it over the letter intended for transmission, and offer a momentary and safe rest, and facilitate manipulation. As soon as the handle is turned the pointers of both indica-

FIG. 217.

tors, of the transmitting as well as of the receiving station, will follow the motions of the handle, stopping at the same letters as the handle. The letters transmitted are, therefore, simply indicated and read off at the receiving-station by noting the stoppages of the pointer of the indicator.

At the end of each word the sender should turn the handle to the blank division of the dial, and at the end of the message should give this blank mark twice. At the end of each word the receiver, whose hand is always to rest on the handle, is to turn it once round, starting from and returning to the blank, which is to the sender the sign of "understood." If, however, the word be not understood, the receiver should turn the handle to R (repeat) and thence to blank.

The dials of the transmitter and indicator are supplied with an outer letter-circle and an inner cipher-circle. In opening telegraphic correspondence the letter-circle is always read off. If the sender wishes to announce to the receiver, that henceforth the cipher-circle has to be read instead, he should give the letter N (number) between two blanks. If he

wishes to return to the letter-circle the letter L (letter) is to be given between two blanks.

FIG. 218.—Siemens Brothers finger-key dial instrument and polarized alarm.

The magneto-electrical dial instrument is shown in Fig. 218. It has two handles, so as to be turned by hand or by the foot as desired. The indicator-dial is placed horizontally on the square transmitter-case.

Signs are transmitted by turning the handle at a speed of about one hundred revolutions per minute, pressing down at the same time with the finger the key of the dial corresponding to the sign or letter to be indicated and resting on it until the pointer stops opposite to it. All the keys of the letters which form the message are successively pressed. Care should be taken not to turn the handle in a contrary direction, as it will come off and no signs be transmitted. The letters thus telegraphed will be indicated, at all the stations in the circuit, by the pointers of the indicators.

The coupling of both of these instruments with the line is very simple. One of the two brass terminals at the back of the instrument is to be connected to the line-wire joining the two stations, the other to a good earth. The instruments are then ready for immediate use. No batteries are required. No adjustments are needed, whatever may be the distance between the two stations. The communication between stations is instantaneous, and a speed of one hundred letters per minute can be attained by a little practice. The instruments are well and strongly made, not liable to get out of adjustment and occupy but little space.

The call-bells, Figs. 217, 218, consist of two bells of about $4\frac{1}{2}$ inches diameter each, and an electro-magnetic arrangement placed between the supports of the bells by means of which a small hammer is made to oscillate, striking against both bells as soon as a call arrives from the distant station, produced by the rotation of the handle of the transmitter. Provision is made by the use of a commutator by which these call-bells are excluded from the circuit while a message is being sent.

TORPEDO APPARATUS.

LIST OF APPARATUS.

Telescopic firing-ares.	Junction-box.
Seven shutter signaling and firing instrument.	McEvoy's single main torpedo system.
Mathieson's improved circuit-closer.	McEvoy's key board.
Torpedo-fuse.	McEvoy's junction-box.
Mathieson's disconnecter.	McEvoy's circuit-closer.
	Kaiser's torpedo alarm.

The exhibit of torpedo apparatus by the Silvertown company was as follows :

Pair of "telescopic firing ares," for firing and converging stations, fitted with telescope, vernier, sights with platinum contacts attached, contact rod, spirit level, and leveling screws.

A "seven shutter signaling and firing" instrument, consisting of automatic relay for switching the torpedo cable from the signaling to the firing battery, a shutter to indicate the number of the mine exploded, and bell to attract the attention of the operator.

"Mathieson's improved circuit closer," used in connection with the electro-contact system, with coiled tapering spring. When set vibrating by the concussion of a passing vessel, this instrument gives a succession of contacts, each of which completes the torpedo circuit.

"Torpedo testing table," fitted with astatic detector, a three-coil galvanometer, key, commutator, Wheatstone bridge, set of resistance coils, and clip for holding a definite length of platinum wire.

FIRING TORPEDOES BY OBSERVATION.

Fig. 219 is a sketch of an imaginary harbor, defended by submarine mines. A and B are, respectively, the firing and converging stations. The firing-station is provided with the battery necessary to explode a mine; a firing-arc, H, and key; a shutter signaling and firing instrument, F, for each group of mines, and a speaking instrument to communicate with the converging-station B. At the latter there are, in addition to the speaking apparatus, three converging ares, C C, and keys, one for each line of mines. A four-core cable connects the two stations, one conductor being required for each line of mines and the fourth (not shown in the figure) for telegraphing purposes.

There are three groups, A A, each consisting of seven torpedoes, moored in three lines, converging, as shown, to the ares C C at station B. Single-core cables connect these mines at the junction-boxes J J with the three

seven-core cables communicating with the firing-station. To simplify the arrangement on shore the conductors are so joined up that each line of mines communicates with a separate signaling and firing apparatus and its telescopic firing-arc.

The firing-arc (Fig. 220) consists of a cast-iron frame, X, with leveling

FIG. 219.

screws and spirit level, and is fitted with a telescope, T, capable of vertical and horizontal movements, and also of being raised and lowered by a rack and pinion motion. The telescope is provided with cross-wires and carries a vernier, *v*, which follows every horizontal movement of the telescope and traverses a graduated scale. A clamp-screw is also provided to fix the telescope in any required position. On the outer arc of the frame are sights, *s*, with metallic V-contacts, *k*, attached to but insulated from the rest of the instrument. The position of these sights and their metallic contacts on the arc are made to correspond with the bearings of their respective mines, as fixed by careful telescopic observation when the torpedoes are first moored; each sight is, moreover, labeled, to indicate the number of the mine. Rigidly connected to the upright which carries the

telescope, and moving with it, is a brass rod, *r*, at the end of which is a spring contact, which passes over and rubs against the **V**-contacts, corresponding to the several mines. This movable rod is insulated from the frame-work and put in connection through a contact-key with the cable

FIG. 220.

leading to the corresponding arc at the converging-station. The converging-arc (Fig. 221) has also a telescope, the sight being very carefully adjusted, so that the axis of the telescope passes through its particular line of torpedoes. The operator at this station is provided with a key, by which

FIG. 221.

he can put the cable leading to the corresponding firing-arc to earth at will.

The shutter signaling and firing instrument, Fig. 222, is in principle an automatic relay for switching the firing-battery *f* into circuit and showing the number of an exploded mine, so that any breach in the line of defense is indicated. In the present instance each instrument, of which there are three, consists of seven relays in one case, i. e., one for each torpedo in one of the three converging lines of mines. Its construction is as follows: Secured to an electro-magnet, *F F*, is an ebonite plate, *D*, through which the soft iron poles *p p* protrude. Between these poles is the armature, pivoted at its center and held back, when not influenced by a current, by a light spring, *S''*, and limited in its movement by screws. A detent,

d , at the lower end of the armature, presses against the end of a pendulous lever, which is pivoted near its center in the bearings b , and has at its other extremity a metallic disk or shutter, 3. A spring, S' (connected with one end of the electro-magnet coils, and the terminal to which one of the contacts on the telescopic observing-arc is attached), presses against a platinum tongue, m , on the pinion of the lever so long as the latter re-

FIG. 222.

main in a horizontal position. But as soon as the current passes from the weak signaling-battery S (generally of only two cells) the armature is attracted and releases the lever, when the disk 3 falls, breaks contact with the spring S' , attracts attention by striking the bell B , and at the same time engages the clip-spring f' , in doing which the firing-battery f (one pole of which is to earth) is switched into the torpedo-circuit T , and the mine exploded. Moreover, the number on the disk, when the lever is in a vertical position, shows which mine has been fired.

In order to bring the above action about it is necessary to put earth on at the terminal leading to the telescopic observing-arc T , and this is done by both the firing and converging-stations pressing their keys simultaneously, for, since the earth-plate E is at the converging-station, it is only by their joint action that the firing-battery can be switched into the torpedo-circuit.

It will be seen on referring to the connections in Fig. 222 that if a good earth be made in the torpedo cable-circuit the same result will follow. This is what actually happens when a circuit-closer is employed in connection with a torpedo, as will presently be described.

Let us take the case of an enemy's ship approaching the first line of torpedoes. The operator at the firing-arc 1, who controls the whole advanced line of torpedoes, follows carefully the movements of the vessel by turning his telescope from one fixed sight to another as the vessel changes position, closing, at the same time, the **V**-contact, corresponding to the sight at which the telescope rests, by means of the contact-rod *c*, and pressing down his key as long as the vessel is within striking distance. Meanwhile, the observer at the converging arc 1 waits till the vessel is crossing his line, and only keeps his key down so long as the vessel is covered; directly after she has passed the line he opens his key. If, while the vessel crosses B's first line, the operator at A cannot cover her suddenly by his sights he does not close his key, because the ship is evidently passing between two torpedoes and on to the second line of mines. The same operation is then gone through between firing and converging arcs No. 2, and only when the vessel is passing over a spot where the lines of a sight on the firing and corresponding converging-arc intersect each other will both keys be down and the torpedo exploded. Suppose the ship to have passed the first line and be crossing the torpedo marked *e*, in the second line, in order to fire that mine the operator at firing-arc 2 will have his telescope on his middle sight and his key down, while the operator at station B will simultaneously be pressing the key corresponding to his telescope, which commands the middle line of mines. In this case, the current from the signaling-battery *S* passes through the coils of the signaling and firing instrument *F* to terminal *T*, to contact of firing-arc 2 (corresponding to torpedo *e*), then to conductor of cable connecting firing-arc 2, with converging-arc 2, and thence by key to earth. The result is that the armature *pp* is attracted, and trips the lever so that the disk falls, breaks contact between the tongue *m* and the spring *S'*, switches in the firing-battery (usually of 100 cells Leclanché), and allows the current to pass from spring *f'* through lever of shutter-bearings, *b*, and so by torpedo terminal, *T'*, to explode the mine. On referring to the figure, it will be seen that, so long as the lever of the signaling and firing instrument is in its normal horizontal position, the terminals *T* and *T'* are virtually one, being in metallic connection through the spring *S'*; hence a circuit-closer, floating above the torpedo (Fig. 223), and operated by the concussion of a passing vessel, performs precisely the same functions as that accomplished by the two operators on shore; in fact, the two systems, firing by observation or intersection, and what is known as the electro-contact system, are generally employed together, and are both en-

tirely independent of each other. It will, of course, be at once apparent that the arrangement of the torpedo-fuse must in each system be different. In the electro-contact system, a platinum wire fuse is used, which has a comparatively small resistance, so that when a ship strikes the circuit-closer and puts earth on, the signaling-battery of two cells is ample to work the signal and firing instrument; whereas, when firing by observation, a high-tension fuse or some electro-magnetic switch arrangement, in connection with a separate platinum fuse, is employed, with a resistance too high for the signaling-battery to work through effectually, but which is readily made to fulfill its function by the heavy firing-battery. The electro-contact system is clearly practicable by day or night, while firing by observa-

FIG. 223.

FIG. 224.

tion is limited to clear weather; but, on the other hand, the electro-contact system, to be operative, requires that a vessel actually strike the circuit-closer, and, taking into consideration that torpedoes have to be moored a considerable distance apart, so that the bursting of one may not explode its neighbor, a breach in the line of obstruction would necessarily reduce the chance of a ship coming into collision with an electro-contact mine, whereas it might easily pass near enough, if not to be destroyed, at any rate to be disabled, by torpedoes fired by observation, so that the one system is a powerful auxiliary to the other.

“Electro-contact system.”—Beyond the three converging lines of torpedoes, shown in Fig. 1, are three groups of mines, to protect the entrance to the harbor; these are fired solely by circuit-closers contained in the buoyant torpedoes and actuated, as the name of the system implies, by direct contact with the hostile vessel.

Branch cables connect the four torpedoes of each group with the junction-box J', where they are joined, through disconnectors, to a single-core

cable, reaching to a second junction-box nearer in-shore; here the three main conductors are made up into a multiple cable, communicating with the firing-station on shore. A signaling and firing instrument, similar to that already described, is joined up in circuit with each of the three main conductors; this instrument switches in the firing battery and indicates the particular group to which an exploded torpedo belongs.

FIG. 225.

The circuit-closer (Fig. 225), known as Mathieson's improved circuit-closer, consists of a coiled, tapering spring, which carries a contact-disk, D, through the center of which rises a spindle, surmounted by a brass ball. The contact-disk is connected to a platinum wire fuse and to the cable by a wire, *h*, but is insulated from the spring and spindle by an ebonite ring. The apparatus has three adjustable contact-screws, equidistant from each other, and set opposite to springs, *e*, the latter being connected through the base of the instrument with the metal of the buoy inclosing it, so as to make a tolerably good earth. It is usual to adjust the contact-screws so that when the instrument is held in a horizontal position, they are just short of touching the earth-springs. Thus adjusted, the circuit-closer is unaffected by the regular undulating motion of the waves, but, should a passing vessel strike the torpedo, the concussion sets the circuit-closer oscillating violently, and repeated contacts are made between the contact-disk and the earth-springs, thus completing the circuit continually and allowing a current from the firing-battery to pass.

The employment of a coiled, tapering spring secures very much more prolonged contacts than was the case when a steel rod was used, as was

formerly the case, and it has enabled Mr. Mathieson to reduce the weight of the ball at the top of the spindle from $2\frac{1}{2}$ pounds to 9 ounces.

Fig. 226 is a vertical section of a buoyant torpedo, with the circuit-closer, fuse, and bursting-charge complete; it is a pear-shaped buoy, with a wooden jacket strengthened with hoop iron, and has a galvanized iron lining. The circuit-closer and fuse at K are placed before a bursting-charge of 2 pounds of dry gun-cotton at R; and the whole is inclosed in a gun-metal shell to exclude moisture. One wire of the fuse is joined to the conductor of the cable which enters the torpedo from below, and the other wire is connected to the contact-disk of the circuit-closer. The interior of the torpedo is filled with damp gun-cotton.

As a torpedo bursting near a vessel is considerably more destructive when it is in actual contact with the latter than when it is submerged at a distance below the surface of the water, it is found necessary to employ 500 pounds of gun-cotton in the latter case, while 100 pounds suffice for surface charges. On the other hand, torpedoes moored as in Fig. 223 command a wider area, and are, on that account, more suited for the firing by observation system. They must, however, be moored at a greater distance apart (generally not less than 300 feet), so that the bursting of one torpedo may not explode its neighbor.

The two conductors of the platinum wire fuse (Fig. 227) pass through an ebonite plug and have their ends tinned and bridged across by a fine platinum wire .003 of an inch in diameter and one-quarter of an inch long. Around the platinum wire bridge, inside *b*, is a small quantity of granulated gun-cotton, and above it rises a tube, *o*, containing fulminating mercury, which is inserted into the bursting charge R, Fig. 226.

When the buoy containing the circuit-closer receives a violent blow, the circuit is closed, and the current from the firing station heats the platinum wire; this ignites the granulated gun-cotton, fires the fulminating mercury, and explodes the mine.

Since all the mines in the system are fired by the same signaling battery, it is evident that, when one torpedo is exploded, the battery would be to earth through the shattered end of the cable. To obviate this defect, Mathieson's disconnecter (Fig. 228) is introduced into each of the branch circuits at the junction box J. It consists of an ebonite plug, *e*, through which pass two india-rubber covered wires, the latter and the ebonite being secured together to form a solid, so as to effectually prevent any moisture finding its way along the wires, even under pressure.

The ends of the wires are tinned and bridged across by a fine platinum wire, *b*, .003 of an inch in diameter, and about one-quarter of an inch long, as in the case of the platinum-wire fuse (Fig. 227). Immediately around the bridge is a film of gun-cotton, and below it and between the copper conducting-wires is a tube, *t*, containing a slow fuse. A small

cap, *c*, containing granulated gun-cotton, is fitted over the platinum wire, and the whole is encased in a cast-iron shell, *g*, the interior of which is made perfectly water-tight by a gutta-percha washer, *w*, placed between

FIG. 226.

FIG. 227.

FIG. 228.

the cover and the base to which it is screwed. When the circuit is completed by a vessel striking the circuit-closer, the current from the firing station fires the fuse in the torpedo, and at the same time heats the platinum wire of the disconnecter in the junction-box, and so fires the granulated gun-cotton. This in turn ignites the slow fuse *t*, which, being very cross-grained, mechanically ruptures the platinum-wire bridge and severs the branch circuit from the system. The cast-iron shell is made sufficiently strong and has space large enough inside to admit of the gas generated by the ignition of the gun-cotton expanding without receiving injury, so that perfect insulation at the break is secured.

It is, of course, essential that the torpedo be exploded before the disconnecter cuts out the branch circuit, and this is brought about by the slow fuse *t*, which allows an appreciable time to elapse after the platinum-wire bridge is heated before fulfilling its function. Another method of breaking the platinum wire is to insert a wooden pin through the small ebonite cap *e*, between the copper conductors and below the bridge, so that when the cap is forced off by the gas expanding, the pin is carried with it and breaks through the platinum wire. In this case, the action of the disconnecter is retarded by using a platinum wire of rather larger diameter than that used for the fuse, so that the latter becomes heated first. The importance of some such simple and effectual means of cutting out a circuit is obvious, as without it it would be necessary to employ a separate conductor for each torpedo.

Fig. 229 shows the interior of a junction-box for the main cable *C*, and four branch cables, *b*. On a small platform inside are holes, into which four disconnectors, one for each branch circuit, are fitted; one wire of the disconnecter is joined to its branch conductor and the other to a plate, *n*.

In the center is a brass plate, C, to which the main cable is attached, and which overlaps the four plates *n*, so that it may be connected to them by thumb-screws. Should it become necessary to raise the junction-box at any time for testing purposes, this commutator enables the electrical con-

FIG. 229.

dition of the branch circuits to be ascertained separately, or any one to be disconnected from the main cable, by unscrewing the corresponding screw.

It is of importance that the firing of torpedoes be controlled from the shore when practicable, so that they may be rendered safe for the passage of friendly vessels, by disconnecting the firing-battery. In certain cases,

FIG. 230.

however, as, for instance, when blockading a harbor or protecting channels, what are known as electro-mechanical torpedoes are made use of. This system differs from the electro-contact system only in employing a submarine battery, Fig. 230. The torpedo, with its circuit-closer, is first

moored with a sinker, and the electric cable towed to a safe distance, when the submarine battery is attached and gently lowered into a position where it may be recovered at will.

On either flank of our imaginary harbor (Fig. 219) are laid down some purely mechanical torpedoes, M M, to complete the line of defense, but, as these are not of an electrical nature, they are not described.

M'EVROY'S SINGLE-MAIN TORPEDO SYSTEM.

The inventor makes the following claims :

In this system of harbor or coast defense the whole of a group of moored torpedoes communicates with the station on shore by a single electric conductor. Along this they continually telegraph evidence of their being afloat and in working order, and upon any one being struck by a ship it gives immediate notice of the fact to an observer on shore, who can, if he thinks fit, instantaneously explode the exact mine without any time being spent in preliminary adjustments. Further, each torpedo can be electrically isolated from the rest, and can then be tested so that the continuity of the electrical connections may be determined or can be exploded without coming in contact with the ship whose destruction is desired.

The single electric cable, which is the medium by which the currents for producing these various effects are conducted, runs from the signal-station on shore to a point in the channel or harbor near where the assemblage of torpedoes is situated, and there enters a junction-box. From this box there emerge as many conductors as there are torpedoes to be manipulated, one going to each, and by means of electrically-controlled apparatus within the box any one of these conductors can be separately placed in connection with the main cable, or the whole may be coupled to it at once. At its other end each conductor enters a torpedo and passes successively through a telephone coil and a platinum fuse and thence to earth. Over the telephone, instead of the usual mouthpiece, there is placed a bell or a box containing loose shot, which, under the influence of the rolling motion of the waves, continually make a noise that can be heard in a telephone at the central station. The fuse is a piece of platinum wire through which a current of moderate intensity can be sent without any danger of heating it, but which can be rendered red-hot by a more powerful current when desired. The arrangement for effecting explosion by concussion consists of a weight held down to a seat by a spring, but not otherwise secured. When the case is violently struck this weight is displaced, and by its motion brings two contact pieces together, diverting the current from the telephone coil and directing it through an electro-magnet, which maintains the parts in the new position until the exploding current is transmitted, or the current is reversed, when the contact is broken by a spring.

Figs. 231, 232, and 233 show the ingenious electrical and mechanical apparatus by which the various operations are effected:

Fig. 231 represents the key-board at the signal-station, Fig. 232 the junction-box, and Fig. 233 the circuit-closer and fuse, all these views being one-fourth of the full size. Fig. 234 is a diagrammatic view of so much

FIG. 231.

of the system as is contained in Figs. 231 and 232, B being the single conductor joining the key-board to the junction-box C, and D D the separate conductors from the junction-box to the individual torpedoes. Each

of the wires D is coupled to one or other of a series of metallic contact-pieces, E, arranged in a circle round the axis of a metallic pointer, F, which can be turned by a step-by-step motion, and thus brought successively into electrical contact with the several contact-pieces E. The current from the main conductor B is first led round the coils of an electro-magnet, G, and then to the axis of the pointer F, from whence it passes to one of the contact-pieces E. In front of the electro-magnet is an armature, H, which is attracted when a current of sufficient strength circulates round the electro-magnet, and is withdrawn when the current ceases. From this armature motion is transmitted to a pawl, which works into the teeth of a ratchet-wheel on the axis of the pointer F, so that by sending a succession of currents of sufficient strength through the cable, the pointer F is turned by a step-by-step motion, and is successively brought into electrical contact with the several contact-pieces E.

FIG. 232.

At the key-board, Figs. 231 and 234, *a* is a handle of a commutator, which in its rotation first connects a battery to the cable for a sufficient length of time to move the index in the junction-box from one contact-piece to the next, and then breaks the circuit. The motion of the index in the junction-box is exactly reproduced upon the dial *b*, so that the operator knows which of the torpedoes is in connection with his instrument.

When the pointer of the dial *b* is brought to zero the pointer F in the junction-box is in electrical communication with a contact-point, which is coupled to all of the branch wires D, and usually the apparatus is left in

this condition. The current from the testing-battery at the firing-point then passes to earth through the resistances in all the torpedoes. If now any one of them be struck by a passing vessel, and its resistance-coils be cut out of circuit, in the way to be presently described, the sudden diminution of resistance will be evidenced at the firing-point by the increased deflection of the galvanometer *e*. The movement of the needle effects an

electrical connection by which a small battery is caused to sound a bell at *e*. The operator can then, if he please, at once fire the torpedo that has been struck, by moving a handle at *f*, and coupling up to the cable a battery of greater strength. The current will divide itself among the fuses, according to the electrical resistances in the various circuits, and as that which proceeds directly to earth has much less resistance than the others, that alone will transmit sufficient current to effect ignition. In cases where there is no danger of injuring friendly vessels the co-operation of an operator at the key-board may be dispensed with,

FIG. 233.

FIG. 234.

and the firing-battery be permanently connected to the cable by the plug on the right-hand side of the bell. (Fig. 231.)

The explosion of the torpedo leaves one conductor, *D*, directly connected to earth, and thus prevents the same system of simultaneous testing being applied to the remainder. To avoid this the wire *D* is then cut off from the contact *E* by the passage of a strong current, which either fuses a connection between the two, or effects the uncoupling by means of an electro-magnet. The operator can tell which of the torpedoes it is that has been fired by passing the index round the circle and noticing the deflection of the galvanometer at each step. For taking more accurate measurements of the electrical condition of the cable and fuses, a Wheatstone bridge is provided, with a galvanometer, *b* (Figs. 231 and 234), and a small box of resistance-coils (shown behind it).

We now come to the very ingenious circuit-closer which is inserted in

each torpedo and telegraphs to the operator at the key-board the fact of the mine having been struck. This appliance is inclosed within a water-tight metallic case, not shown in Fig. 233, and is screwed into the base of the torpedo. It contains, in addition to the fulminating-fuse, a quantity of dry gun-cotton. Damp gun-cotton, as is well-known, can be handled with great safety, and cannot be exploded even by an ordinary fuse of the usual dimensions, but if the fulminating-tube be surrounded by a small quantity of dry gun-cotton, then ignition will be conveyed to the whole, and damp cotton may be employed with the advantage of greater security and no loss of effect.

From the base of the apparatus there rise two pillars carrying four distinct appliances; first, an electro-magnetic contact-maker; second, a tumbling weight inclosed in a case; third, a telephone; and, fourthly, at the top, a fuse. The current normally enters through the base, passes up an insulated wire on the side of the case containing the weight, enters the telephone-case on one side, and, after traversing the coils, comes out at the opposite side, and goes through the fuse to the body of the apparatus, which is the "earth." Under these conditions, the sound of the bell or the rolling shot can be heard in a telephone-receiver at the key-board. When, however, the torpedo receives a shock, a weight, which can be seen where the case is broken away, and which is normally held to its seat by a spring, is displaced, drawing up a rod upon which is mounted the armature of the electro-magnet and a contact-piece. The effect of this is to put the magnet-coils into circuit and to short-circuit the telephone-coils. The electro-magnet attracts its armature, maintaining the contact-piece in its new position, and the current now flows direct to the fuse and thence to earth, and, if the firing-battery be in circuit, the torpedo explodes. In case the collision should have been caused by a vessel whose destruction is not desired, the operator momentarily reverses the current by the key *i* (Fig. 234), and the armature falls away, carrying the contact-piece with it, and the current returns to its former course.

The case we have been describing, viz, that of floating torpedoes, is evidently much more complicated than that in which the mines lie upon the bottom, or are buried in the sand. In such circumstances, a very much simpler circuit-closer would, of course, suffice, as the mines must be fired by observation.

NOTE.—Reference is made to a more detailed description of this system, published February 10, 1883, in Ordnance Notes No. 244, describing, also, McEvoy's submarine detector. Experiments were made with the latter at Willet's Point, N. Y., but did not prove satisfactory. The single-main system, depending for its success upon a modified Wheatstone dial-telegraph, in the junction-box, sunk under water and unap-

Magnetic contact machine

Top figure: Side view

Middle figure: Bottom view

Bottom figure: Top view

d and d' Solenoids of great resistance without core

e, e'. Magnetic needles resting in d' on steel knives

e'. Weights for changing the centre of gravity and liberty

l and l' Steel knives on which the whole apparatus moves,
resting in the steel plates with circular holes in
the brass axes s and s' (right hand figure)

β and β' Brass supports for the knives

r
Pieces of shunts for insulation. The bottom figure
shows the direction of the current

Torpedo Alarm

Half size

a and b Neck through which the wire is led into the alarm

c and c' Upper hemispheres with rim

d Ring of vulcanized caoutchouc

f' Leadon weight to make the alarm (without mine) sink and thus to try it separately

Full size

Fig. 242

Hemisphere with rim and neck

a Nut with cylindrical entrance for the telegraph cable to prevent slipping of core

b Brass tube

d Brass tube

e Ring of vulcanized caoutchouc

f' Elbow ring

g Brass pin with an elastic feathered head pinching the wire of the cable after it has been laid bare

f' Piece of elastic insulating the brass pin and the hemisphere

b' Brass ring holding up brass pin and insulator

c' Brass connecting-piece for tube b

h Axle for the outer cardanous ring

c Upper hemisphere with rim

h' Second axle for the outer cardanous ring

i Gib for the bent arm to which the axle h' is attached. When the alarm globe is closed this gib touches the inner side of the second hemisphere

proachable, seems to me to be deficient in that certainty belonging to a multiple-main system, for, should the dial fail to work accurately, the wrong torpedo might be exploded.—D. P. H.

PRINCIPLE ON WHICH DR. P. J. KAISER'S DYNAMO-ELECTRIC TORPEDO
ALARM IS FOUNDED.

(Described by himself.)

Some time ago the idea struck me to make an iron-clad ship through its magnetism betray its presence above a mine both by day and night. Every iron-clad naturally possesses magnetic polarity which is able to cause a magnetic needle outside this ship to be deflected from the position given to it by the earth's magnetism. This motion or change of position of the needle may be utilized for the interruption or making of a galvanic current, which, again, may be used to bring into motion at a great distance from the vessel a magneto-electric apparatus and to make it give an audible or visible signal. So, if in or near a mine be placed a magnetic needle which answers to the above conditions, it will be possible, every time when an iron-clad passes over it, to mark on land the exact moment at which the ship is above the mine. But it entirely depends on the nature of the contrivance which contains the needle to secure success for the execution of this idea.

The conditions which the apparatus must answer to be of practical use towards reaching the above end are principally the following:

1st. In whatever magnetic azimuth the needle of the apparatus may be the same force must always be required to change its position to the extent of a certain angle.

2d. It must be of no consequence whatever in what direction the iron-clad passes over the apparatus. The needle must always at the same distance from the vessel suffer the same deflection.

3d. It must be possible to put the apparatus in the water without the employment of any other contrivances, as diving-bells, &c.

4th. No matter in what way and in what position the apparatus has reached the bottom of the water it should be ready for use when it has got at rest.

5th. The apparatus must be arranged in such a way as to cause a current to be transmitted, not interrupted, when a ship passes over it, so that the batteries are not working generally, and thus will not be corroded so soon.

6th. The closing (making) of the contacts must be certain, even when the disturbing magnetic power of the vessel is very slight.

7th. When friendly vessels have made the apparatus speak, it must be

possible to put it in order again for future services, in the place of the observation, without being lifted.

8th. The apparatus must be simple enough to require no great pecuniary expenses and be able to do service for years.

These conditions may be fulfilled by a magnetic needle, which, being in equilibrium through the working of the earth's magnetism and gravitation or some other force, keeps a current interrupted, whilst, when its equilibrium is disturbed by the magnetism of some passing vessel, it is brought into contact with a piece of metal, and so causes the current to be closed. It is easy to convince one's self that a magnetic needle turning as in the case of a rose, on a pivot in a horizontal plane, cannot fulfill the three first-mentioned conditions.

If the magnetic needle is altogether free it returns, after having been disturbed, with too little force to its magnetic meridian, and the equilibrium will be too uncertain on account of the friction on the pivot. Besides, the influence of the vessel on the magnetic needle would entirely depend on the direction of the ship with regard to the needle. None of these objections can be raised when the needle is pivoted on a horizontal axis, so that it can move a little in a vertical plane, and is kept in a horizontal position by the influence of the earth's magnetism and a weight attached to the pivot. The axis round which the needle must be able to perform short vibrations may be suspended in rings of Cardanus, so that it must always remain horizontal, no matter in what position the box containing the apparatus reaches the bottom of the water. If the weight is placed in such a way that the needle, being at rest, adopts a horizontal position, it will remain so for all the azimuths of its axis. In order to become convinced of this truth, resolve the force which the earth's magnetism exercises on one of the points of the needle, in three directions, viz :

1st. A direction parallel to the horizontal axis of the needle.

2d. A direction falling together with that of the horizontal needle, and so perpendicular to the axis; and

3d. The vertical line going through the point of the needle.

These three resolutions of the force are perpendicular to each other. The first two are entirely neutralized by the axis, and the third marks the force with which the earth's magnetism tries to make the horizontal needle move round its axis, *i. e.*, in a vertical plane. If the direction and force of the earth's magnetism be represented by a straight line, the three resolutions before mentioned are the projections of this line on the three adopted directions. So the resolution in the direction of the vertical line, *i. e.*, the force with which the earth's magnetism tries to disturb the equilibrium of the horizontal needle, is equal to that magnetism multiplied by the sine of the angle, which is called the dip or inclination. This holds good for all

Semispherical Mine with Torpedo Alarm

the azimuths in which the axis, and, therefore, also the needle, can be brought. The working of the earth on the vertical motion of the needle is the same for all azimuths, and if the needle is once horizontal, it will continue to be so in all azimuths.

The same way of reasoning may be followed to show that the force with which a passing vessel tries to raise one or the other point of the needle is entirely independent of the magnetic azimuth of the needle and of that in which the ship is placed with regard to the needle.

If the needle is in equilibrium in a horizontal position by the combined working of the weight and the earth's magnetism either one or the other of its ends will be raised by a passing vessel according as one or the other pole of the vessel approaches the needle first. If a metallic plate be placed above each end of the needle in such a manner that the needle in its position of equilibrium touches neither of them, but must touch one of them when by a passing vessel one or the other point of the needle is raised, each of these contacts may close the same current, and this current will then betray the presence of a vessel above the needle to an electro-magnetic apparatus placed on land at a distance taken at liberty. Of course hoops and weights should be applied by which, in the position of equilibrium, the plates are kept at a proper distance from the needle in whatever manner the apparatus comes down on the bottom of the water.

According as the weight under the needle is heavier it will the easier surmount the friction on the axis and make the needle return more accurately to its former position of equilibrium, but to the same degree a vessel will require greater magnetic force to press the needle against one of the metallic plates. It may be asked whether this force, in a fairly deep water, would be generally sufficient to make the contacts of the metals so close as to cause a galvanic current of some strength to be made. I should not undertake to answer this question in the affirmative if I had not found a means to produce a close contact when the metals only slightly touch one another.

It is not possible altogether to save the metals by the contact of which a current must be transmitted from being tarnished or covered with impure substances, so the metals must be pressed against one another with a certain amount of force to allow of a free passage for the current. When there is a slight contact a very weak current is transmitted, though it may be too weak to betray itself to a common galvanometer. Above the ends of the magnetic needle I have placed small solenoids, through which that weak current is to flow, in such a way that when working on the needle this is pressed with great force against the metal. The consequence is that a stronger current must flow along the coils, which in its turn presses the needle with the greater force against the metal still.

In this way the contact and the current work to strengthen one another

mutually, and a very slight touching of the metals is changed into a very close contact.

As the contact may occur at either end of the needle each end is furnished with a solenoid.

Together with this explanation of the principle on which the apparatus is founded the accompanying drawings will suffice to convey a clear notion of the way in which the instrument has been contrived.

P. J. KAISER.

REPORT OF THE EXPERIMENTS WITH DR. P. J. KAISER'S MAGNETO-GALVANIC TORPEDO ALARM, MADE BY THE TORPEDO SUBCOMMITTEE IN THE SUMMER OF 1873.

Permission having been obtained in March to purchase the solenoids required for the first experiments the subcommittee conferred with Mr. Kaiser concerning the fabrication of these instruments. The instrument-maker, Boosman, at Amsterdam, who had been charged with their fabrication, could not have them done before May 12.

In order to have everything ready by that time for the commencement of the experiments H. M. gunboat No. 7, belonging to the material of the marine torpedo service, was sent from Amsterdam to Willemsoord, with two officers and part of the inferiors of that service for making the necessary preparations off der Helder and the coast of Texel. The members of the subcommittee belonging to the navy had previously examined the position Helder-Texel at Helder, as to which battery, with respect to the position of the torpedoes, would be the most suitable for firing heavy cannon; at Texel, as to which would be the most favorable place for making experiments.

Only the "Wierhoofd" battery, the East battery, and the battery "Kaap-hoofd" could be taken into account for the firing experiments, as no others were armed with cannons of 24 centimeters. After having considered the advantages and disadvantages attached to these batteries, the East battery was fixed upon for the experiments. At Texel, the sea to the north of Oude-Schild harbor was thought fittest.

The detachments of the land and marine torpedo services arrived at Nieuwediep on the 1st and the 2d of May.

All the operations in connection with the experiments have been superintended by the temporary head of the marine torpedo service, who could dispose of the two detachments.

On the 13th of May all preparatory arrangements had been made, the ground and the water near the East battery had been examined and charted as far as necessary, the station for the observations had been erected, the cables had been got ready, and the buoys had been laid. The alarms,

Companitor

Fig. 245

Fig. 246

Fig. 247

Fig. 248

Fig. 249

Fig. 250

Fig. 251

Fig. 252

Galvanometer

Full size

Fig. 253

Fig. 254

Fig. 255

Fig. 256

Fig. 257

Fig. 258

with everything else belonging to them, arrived at Nieuwediep on that day, and the next day Mr. Kaiser commenced placing these instruments in their proper position for betraying (detecting?) a monitor in 7 meters of water. This position had been ascertained in 1871 by experiments on the Y with H. M. monitor Cerberus and some alarms. (*Vide* pp. 34, 35 of the Torpedo Annual Report, 1871, of the then Captain Lieutenant (R. D. N.) van de Velde, contained in the 15th volume of "Navy Intelligence.") In order to be able to reproduce this position at any time, Mr. Kaiser had determined the greatest distance at which an alarm, that in the above-mentioned position had betrayed the monitor at a favorable moment, could be made to speak by one of the poles of a magnetic bar, the force of which was known and had been now and then controlled.

The simple contrivance by means of which he determines this distance is called a comparator. In order properly to betray H. M. monitor Cerberus in 7 meters of water it was ascertained that the distance between the center of the globe in which the alarm is contained and the north or south pole of the magnetic bar of the comparator would have to be somewhere about 32 centimeters.

Besides, for the second firing experiment on the 30th of May and for the last crossing experiments, from the 8th till the 11th of October, experiments were made continually during last summer with alarms, whose degree of sensibility was indicated by the above-mentioned number, when they were regulated quite satisfactorily.

For practical use, however, it was Mr. Kaiser's opinion that for betraying a monitor in ± 7 meters of water this number is reached to within 5 centimeters. The placing itself, the regulating of the distances between the contacts of the apparatus, should not be done in a hurry. It takes up rather much time, as an alarm, when its exact sensibility is to be found; must stand still for a quarter of an hour at least after each observation before we can be sure that the apparatus is at rest. It is impossible to place it delicately with very great correctness unless the apparatus can come to a perfect stand-still for several hours running after each change in the distance of the contacts; if this does not take place, we get at results which make the instruments seem more sensible than they really are.

Two days were required for putting the six alarms in their position, or rather in their exact position, for Mr. Kaiser had already got his apparatus nearly ready by fixing the distances between the contacts somewhat at a guess, of course by making use of results obtained before. It was then found out that the construction of some of the minor parts of the alarms was not right in every respect. It frequently occurred that Mr. Kaiser thought he was placing one of the alarms more delicately when the reverse was shown by his further examinations with the comparator, or, again, that after alter-

ing the position of some instrument no change in its sensibility was noticed. A difference of 2 centimeters and more was sometimes noted, when two observations were made for fixing the distance at which an alarm spoke near one of the poles of the comparator, when no change whatever had taken place with the instrument. To some extent, pinching of some of the minor parts of the instrument and thickening of the oil may have been the cause of this, but it may also have been owing to the rather unsuitable place in which the alarms had been put up (a wood-shed on the yard, which was rather dusty, may have occasioned it). Some of the alarms had to be readjusted three and four times before their sensibility was sufficiently regulated, No. 5 even five times.

The subcommittee, as well as Mr. Kaiser, thinks it very likely that these little defects in the apparatus will to a great extent be remedied by making solid those parts which were detached before, and by a better, more accurate construction of the composing parts.

The 16th of May the six copper* mines with alarms were ready to be laid down in Helsdeur for ascertaining whether the firing of some shots from a heavy cannon placed on the bank of some water would have a material influence on the alarms lying not far off on the bottom of that water. The positions which the alarms had then are stated in Table A, subjoined to this report.

The solenoids destined to produce the magnetism required for examining the condition of the alarms, and thus replacing the actual crossing of a vessel, were inclosed in copper kettles, the top side of which touched and was fixed to the lower half globe of the alarm.

When the alarm was placed in the mine and screwed on to its interior wall, the bottom side of the kettle was still about 1 centimeter away from the bottom of the mine.

In the laying of the mines we were not very successful, for it took eight days, partly on account of the want of practice of the men and the not so very favorable weather, partly because we were obliged to lift the mine with alarm No. 2 a few days after its having been put in its place, for in the first twenty-four hours it refused to work, when its cable was connected with the alarm-battery and its solenoid received the current from the bobbin-battery. Then it began to speak without the application of its bobbin, and continued doing so. Consequently a contact had been caused within the apparatus. After having been lifted out of the water and put on land for examination it worked properly. On opening the globe of the alarm, nothing particular was seen in the apparatus. It was then replaced in the water, and after that remained in good condition.

* It was Mr. Kaiser's wish that the difference between *copper* and *brass* should not be observed in the translation, as it would sufficiently appear from the context which of the two is meant.—TRANSL.

Experiments on the 26 and 30th of May 1873
(Firing Experiments)

FF marks the places in the East Battery of the four 24 C.M. Cannons
G. Torpedo Station.
B. Bearing instrument.
I, II, III, IV, V, VI, VII Places of the alarm mines on May 26th
V, VII, IV, I' 30th

Alarm mine I lay at a depth of 3.7 metres at 59 metres distant from the battery

II	18.5	93
III	17.0	142
IV	28.5	192
V	30.5	242
VII	31.5	275
VII'	19.0	100
V'	25.0	110
IV'		42
I'		60

Horizontal projection of the positions of the mines (at 200 ft)

Alarm mine I at a depth of 8.5 metres from the iron sleeping mine 99.8 metres

II	8.5	70.98
III	8.3	44.26
IV	8.4	32.83
V	8.2	15.72
VI	8.0	11.95
VII	8.5	19.95
Iron mine	8.5	

NB The depths of the water are stated in metres during low water (1m under high sea)

Experiment on the 19th of June 1873 (1st springing experiment)

Alarm mine IV at a depth of 6.7. Medusa distant 100 from the iron sleeping mine 100 meters									
.	.	V	.	.	5.5	.	.	.	45
.	.	II	.	.	6.7	.	.	.	45
.	.	VII	.	.	8.4	.	.	.	45
.	.	I	.	.	4.0	.	.	.	67
.	.		.	.	6.2	.	.	.	

NB The depths of the water are stated in metres during low water (1 metre under high sea)
Mine II useless during the experiment

Experiment of the 30th of July 1873 (2nd springing experiment)

On winding up the last one of the cables lying in the water, the one for the bobbin of mine No. 2, on the 20th of May, this cable, by the strong current, pulled the kedge off the buoy at which the long-boat lay that had been used for the operations, so the kedge of the long-boat had to be let down for awhile. On its being lifted, a small anchor of ± 70 kilograms, old and half corroded, was pulled up. In the opinion of the subcommittee it is not impossible that this anchor was the cause of the contacts of alarm No. 2 being constantly closed from the 19th of May up to the day when its mine was lifted and placed anew.

Alarm No. 1 repeatedly spoke without a galvanic current passing through its coil. This was always the case with a violent wind or a strong current, and it was at rest during a calm or the turning of the tides. As this alarm was placed very close to the shore in shallow water, it was ascribed to the current as well as to the often violent beating of the waves that the contacts of this apparatus were repeatedly closed.

The working of the solenoids was greatly variable. At first they were used with a battery consisting of 16 elements of Leclanché, connected in series. A great many times it could not transmit a sufficiently strong current to a bobbin for making the corresponding alarm speak. A few times, however, all the alarms were got to speak at a time by sending a current from the bobbin-battery into all the bobbins. Afterwards the bobbins were mostly used with a series of 32 elements of Leclanché connected together, and as a rule they worked properly. And even then it occurred a few times that an alarm spoke, not when the current which was to pass through the coils of the bobbin or helix was made, but when it was suddenly interrupted, the work then being done by means of the stronger extra-current.*

On the 24th, the six mines, with alarms to be employed for the experiments, lay in the water. (The seventh alarm, No. 6, could not be used, because Mr. Kaiser had to make a slight alteration which the others had undergone already.) Cables, mines, alarms, bobbins, &c., were all in proper order as far as this could be judged of.

The upper left-hand figure on plate opposite shows the position of the mines and buoys, and the places where the torpedo station, the bearing instrument, and the cannons to be fired with, were put up.

The way in which the mines were laid down in their places, fixed upon beforehand, was similar to that in which it was done at the time of the experiments on the Y by the marine torpedo service. A long-boat was fastened between four hawsers in such a way that a flag-staff with flag being kept exactly above the center of the mine, hanging underneath the

* By extra-current I mean the current which is induced when the main current is suddenly interrupted.—TRANSL.

hoist* of the long-boat, came precisely in a direction marked by two beacons erected somewhere in line A A' from B, where a bearing instrument was placed successively on the angles A B I, A B II, &c., measured beforehand. Signals were sent by means of three flags, whether the vessel was to bear in with or off the shore, or lay in a proper direction.

On the 26th of May, the day fixed for the first firing experiments, all the alarms were once more tried and found in the best order, a few moments before the firing of the cannons commenced. The battery for the helices was then interrupted; all the alarms were then in electric connection with the alarm-battery and with their galvanometers. After this there was first fired from the East battery a shot without ball, from a cannon of 22 centimeters; then a shot with a cartridge and the charge of 24 kilograms from a cannon of 24 centimeters, and finally, two simultaneous shots with ball from two cannons of 24 centimeters, with charge and projectile as before.

The vibrations caused by this firing had no notable influence on the alarms. The needles of their galvanometers, placed on land, remained at rest. Every time, directly after a shot had been fired, the helices were applied, when the alarms were found to work just as well as before the experiments.

So it was proved, that if for betraying a monitor in ± 7 meters of water an alarm be placed in the water at a depth of 3.7 meters (low tide), at a distance of about 15 meters from the shore, and 59 meters from the muzzle of a 24-centimeter rifled gun, this alarm is not disturbed by a shot with ball and heavy charge from that cannon, nor yet by the simultaneous firing of this cannon and a second one placed in its neighborhood.

By this gratifying result the subcommittee thought itself justified in making another experiment, and in making attempts, which might possibly lead to a solution of the question by firing a heavy cannon over a couple of alarms placed as delicately as possible close to the shore.

The mines with the alarms Nos. 5 and 7, which had been laid in the water last, were lifted that very day, and Mr. Kaiser set at once about giving them a greater sensibility. For this purpose the two instruments had to undergo a slight alteration, which caused a great loss of time, so that it took up two entire days to get them ready. After every change they had to stand still for hours together, before it was thought certain that they would really remain motionless. The least shake of the deal floor in the marine barracks in which the alarms were placed was sufficient to make the contact in the apparatus. Not until they had got at perfect rest in this room, from the evening of the 28th to the morning of

* Hoist (?). Beam standing out at the bow of a ship, and furnished with a pulley to raise weights, &c.—TRANSL.

the 29th of May, did Mr. Kaiser succeed in determining their sensibility. (*Vide* Table A.)

Both alarms were tried and found to be in good condition before being laid in the water; this done, No. 7 was upon examination found to work properly; of No. 5 the contacts were closed so it could not be used. According to Mr. Kaiser, the position of No. 5 was such as to render it practically useless on account of its very great sensibility, even if it had worked satisfactorily. No. 7 he had made sensitive to the highest degree he could reach with the apparatus as they were then constructed.

In the afternoon of the 30th May, the mines with alarms Nos. 1 and 4 were placed, in which apparatus nothing had been changed regarding their position on the 16th of May; No. 1 was set down upon the Helder sea-dike at 60 meters distance from the 24-centimeter cannon which was to be fired with, the other one below that dike at 42 meters distance from this.

These alarms having been tested and found in good order like No. 7, and then connected with the alarm battery and their galvanometers, a shot with ball and heavy charge of 24 kilograms was fired from the 24-centimeter cannon. None of the galvanometers of the alarms got into motion. When immediately afterwards a current was sent through the solenoids, all the alarms worked as before the experiment.

The subcommittee had no hesitation in concluding from this experiment that the firing of heavy cannon placed upon the bank of a water does not make Dr. Kaiser's alarms useless for a time.

So the examination of this part of the programme was considered to be finished. During the further proceedings some alterations have been made in the alarms, *e. g.*, stronger magnetic needles have been introduced, after which alarms, arranged to betray monitors in ± 7 meters water, were not only quiet within a few minutes after changing their places or positions, but, whilst standing on the ground, they could suffer a rather strong push without beginning to speak.

In the beginning of June, the instruments, &c., lying in the water were lifted and put away; the station on the Helder sea-dike was removed; tuns, buoys, and beacons were taken away; the cables were examined, and, as far as necessary, repaired, and, on the 9th and 10th of June, the men and the materials appointed for the experiments were sent off to Onde Schild.

Already in the latter half of April the water in the neighborhood of the harbor of this place had been examined so a line could be adopted immediately in which the mines should be laid for the execution of the second part of the programme, to examine to what extent alarms suffer a disturbing influence from a springing mine (*i. e.*, a mine which could be fired) in their neighborhood. (For the places of the buoys, beacons, stations, &c., see upper right-hand figure on plate opposite page 253.)

To save trouble the mines were placed in a direction nearly perpendicular to the coast-line, the depth being of less moment, as the coils were going to be applied. The principal thing to be taken care of was that the iron sleeping mine* should lie in about 6 or 7 meters depth of water, and that the differences between the other mines should not be too great.

On the 11th Mr. Kaiser had come to Texel and commenced cleaning the instruments, which, for this purpose, had been brought to a room in the Oude-Schaus. This had proved to be necessary, as a little fine sand had got into all the apparatus when they were placed on the 14th and 15th of May. He put the alarms in their position the next day, after which the alarm mines, being altogether ready, could be tested by means of solenoids. All the alarms were found to be in the best order. On the 13th of June we commenced putting the mines with alarms in the water after having examined them once more on land, in the same way it had been done on the previous day.

Alarm No. 3 proved to be useless, its contacts constantly remaining closed, so it was discarded. The other ones worked all right. In the mean time it had also been tried whether parts of a telegraphic cable with iron wire wound round it exercised any material influence on the alarms if brought within a short distance of the mines. A piece of cable, 18.8 meters long, covered with iron wire, and wound in coils of 0.5 meter diameter, was found to make all the alarms, except No. 7, speak when it was brought close to that wall of the mine which was nearest to the alarm.

Pieces of cable covered with iron wire have been used for the first springing experiments and the Helsdeur experiments only.

In order to be safe from any possible disturbing influence of those pieces of cable on the alarms, other pieces, covered with a brass band, were employed for the mines, which lay in the water during the second springing (firing) experiments. As these pieces of cable did not answer well (they were too weak, the brass band soon snapping off in several places and then cutting through the insulation), they were marlined for all further experiments.

The paying out of the mines was done with brass chains for the first experiments; afterwards, when the bottom sides of the mines had to touch the bottom of the water, hempen ropes were employed. The spare ropes† were also made of hemp, so there was no iron in the proximity of the mines.

In connection with the springing experiments to be made, it was also ascertained in which case an alarm, disturbed by a more or less strong

* By a *sleeping mine* I mean to say a mine which lies on the bottom of the water in contradistinction from a mine only just submerged in the water.—TRANSL.

† Spare rope: Rope fastened to the mines and used in case the main rope should break.

motion, would continue longer in motion, when the galvanic current is closed and interrupted very frequently and with intervals, or when between two observations ten or twenty seconds are allowed to elapse. It was found to make no difference either way, so it was resolved upon that, immediately after the betraying of the apparatus in consequence of the springing of a sleeping mine, the current should be interrupted and that the condition of the alarms brought into motion should be looked after with short intervals. All else being the same, it was, of course, in this way possible to determine with greater precision when an alarm which had been useless for a time could do service again.

On the 16th all the mines lay in the water ready for the experiments. During the time the alarms for this first springing experiment were lying on the bottom of this water, a phenomenon was distinctly marked for the first time, to which we shall afterwards have to refer very frequently.

Alarms had been examined and found in good order before their being laid in the water, as also after this; that is to say, when the galvanic current passed through their coils; when afterwards experiments were made with them, when iron-clads crossed them, they were, after lying in the water for a shorter or longer time, found to be speaking, without the influence of those coils or of the iron-clads; after having continued in this state for a few seconds, minutes, hours, days even, they got into proper order again; sooner or later they repeated the same thing or they remained all right for the rest of the time of their lying in the water. The subcommittee called this phenomenon untimely speaking or untimely betraying.

Except No. 6, which was not used for all the experiments, all the alarms have spoken untimely. As in the course of the experiments this phenomenon was noticed several times, we give a survey of these observations in Table E, subjoined to this report. It also contains what happened in Helsdeur with the alarms Nos. 1 and 2 with respect to their being useless for a time.

On the 19th of June the subcommittee met at Onde-Schild to make the springing experiment. The alarm mines and the iron mine were situated, as shown on plate opposite page 253.

As the alarms Nos. 2 and 3 were not fit to be used, we were obliged, to some extent, to deviate from the programme of our experiments. The original plan was to ascertain, also, whether the duration of the vibrations, caused by the springing of a sleeping mine, could be influenced by various depths of the alarms placed equidistant from this mine. This part of the experiments was abandoned, as there was only a mine at a distance of 25 and 45 meters, as also at 10 and at 70 meters' distance. However, the number of mines was then thought sufficient for finding out to what extent the time during which alarm mines are useless is influenced by

their longer or shorter distance from a springing sleeping mine of a gunpowder charge of 100 kilograms, so the subcommittee resolved to make the experiment without making any further change in the position of the mines. About 5 minutes before the springing of the sleeping mine all the alarms which were lying in the water were found in order except No. 2 (No. 3 had not been laid). The needles of their galvanometers were deflected when for the alarms, which were electrically connected with the alarm battery, the current in their solenoids was made.

The springing of the sleeping mine of 100 kilograms gunpowder, which lay at a depth of 6.2 meters in the water, and threw up a column of water amounting in height to 36.5 meters, had the following effect on the alarms: No. 1, 67 meters distant from the sleeping mine, remained useless for nearly one minute, as the needle of its galvanometer after having been quiet for some few seconds after the explosion, was deflected for ± 45 seconds every time, when the current of the alarm-battery was made again, after having been interrupted. This alarm was then again tried by means of its bobbin, and proved to be just as fit for use as before the springing of the iron mine.

The alarms Nos. 4, 5, and 7, which were lying at a distance of 10, 25, and 45 meters respectively from the springing mine, had become altogether unfit for use. No. 2, which lay at the same distance from the sleeping mine as No. 7, and whose contacts were closed already before the experiment, proved to be in proper order on being tried on shore away from out of its mine. It could not be ascertained what was the cause of its contacts being closed for the greater part of the time it had been lying in the water for that experiment.

Of No. 4, 5, and 7 the apparatus were found on the bottoms of the alarm-globes. After examining their mines, it was thought most probable that the bobbins had been the immediate cause of the three last-named alarms having become unfit for use in this way.

When the sleeping mine was sprung, the bottoms and lids of the nearest alarms were crushed (the bottom of No. 4, 44 millimeters).

As the bottoms of the kettles of the solenoids, as has been mentioned already, were originally but 10 millimeters apart from the bottoms of the mines, the subcommittee thought at that moment, that the alarm had got into disorder by the shock arising from the striking together of the kettles of the solenoids and the alarm-globes attached to them (the impressions of the kettles on the bottom were quite distinct). After the next springing experiment, however, for which no solenoids were used, two more apparatus were found lying on the bottom of their alarm-globes. So it seems that the solenoids had not exclusively caused this disorder.

Alarm No. 3, which had not been in the water, was also examined. The contacts in this apparatus were very close together. It even seemed to the

subcommittee that they were made. Dr. Kaiser told them that especially the needle of this alarm was very little magnetized, for which reason the contacts had to come very close together for the regulation of the apparatus.

He thought he should be able to show in a perfectly quiet place that the contacts were not closed. But in consequence of what had happened to this alarm, he had the intention to furnish all the apparatus with stronger magnetic needles. The subcommittee resolved to repeat the experiment without using solenoids in the mines, and permission was asked to employ one of the turret-ships lying at Nieuwediep for testing the alarms a moment before and after the springing of the sleeping mine.

No other position being known than the one repeatedly given to the alarms to betray H. M. monitor Cerberus in ± 7 meters' depth, it was thought that alarms of the same degree of sensibility lying at a depth of 7 and 8 meters would also speak when crossed over by a turret-ship. As these depths were not to be found over the length of about 120 meters which was required in a direction perpendicular or nearly perpendicular to the shore, another torpedo line had to be looked for.

The new space for the experiments was about 800 meters to the northeast of the former, and at a depth of 7.8 meters there was found a hard sandy ground and a line of sufficient length.

The sea-dike of Onde-Schild, south of the harbor, was convenient to place two beacons furnished with flags, which marked the direction for the torpedo to be laid in. The necessary buoys were placed in the water for the steamboat to be fastened to them, which was to put out the mines and point out the course of the turret-ship destined to cross the mines; and that part of the water in which the vessel was to move about for the experiments was sounded and charted. The southern torpedo station was also erected 800 meters further north, so that the mines could be placed more accurately and the cables could be taken shorter. The northern station kept its position; they were in telegraphic communication with each other. (See lower plate opposite page 253.)

In the mean time the alarms were, according to Dr. Kaiser's instructions, repaired and cleaned by the instrument-maker, Boosman, and at the same time these apparatus underwent some changes.

As the construction of the alarms must be kept a secret, these changes cannot be taken down in this report. It should be mentioned in this place that Mr. Kaiser had executed his above-mentioned plan of furnishing the apparatus with stronger magnetic needles and that these modifications, according to the opinion of the subcommittee, could make no difference to the results already got at with the firing of heavy cannon.

On the 16th of June the alarms reached Oude-Schild again. The same day Mr. Kaiser finished placing the apparatus in the globes (they had

been sent from Leiden in a box purposely made for them) and verifying the position he had given to the apparatus at Leiden. (*Vide* Table A.)

The relatively great difference between the positions of alarm No. 3 at Leiden and at Texel induced Mr. Kaiser to open and examine this apparatus. A slight defect he noticed in it was soon remedied without any further changes in the apparatus. It was then again placed in the globe and once more put in its position. (*Vide* Table A.)

With respect to No. 5, too, the difference between the positions at the two places was rather considerable. (See the same table.) So it was left at rest for more than half an hour after the observation, when its position was once more examined and now found to be about the same as at Leiden. When afterwards the alarm-globe, which was with its neck in a vertical direction, was turned round 180° in the horizontal plane the rim was in the same position as at last obtained as at Oude-Schild after the first observation. It was Mr. Kaiser's opinion that the slight difference noticed in the sensibility of the other apparatus at Leiden and at Texel were owing to the fact that at Oude-Schild the control could not take place with sufficient accuracy. It was a wooden floor on which the apparatus stood and it shook considerably when the controllers walked about, whereas at Leiden they had been standing for the same purpose in the marble hall of the astronomical observatory.

On the 17th the mines were filled up and got ready in the ordinary way. The connection of the alarm-globe with the interior wall* of the mine, however, had been modified. Until now it had been done simply by means of the five long screw-bolts, which at the same time served to join the two half spheres of the alarm-globe. In order to diminish the vibrations, two vulcanized (caoutchouc) plates of 1 centimeter thickness were now placed between the interior wall and the rim of the bottom half-globe, just where those screw-bolts were passed through; in the same way one caoutchouc plate with a brass plate† on it, was placed between the rim of the top half-globe and the nuts of the screw-bolts. Besides, a separate metallic junction of the alarm-globe and the wall of the mine was provided for.

The mines with alarm now being ready for use, they were tested and found to be in proper order. As we could not make use of the solenoids now, this was done by means of a magnetic bar, which was held against or at a short distance from that part of the side-wall of a mine which was nearest to the alarm, after having first electrically connected this apparatus with a galvanometer of a galvanic battery.

On the 17th, 18th, and 19th of July only one mine could be put in the water, on account of the rather unfavorable weather, but on the 21st the other five followed.

* Partition.

† To preserve the caoutchouc.—TRANSL.

Whilst the alarms were lying in the water for these experiments, a couple of apparatus were again caught speaking untimely. (See Table E.)

H. M. turret-ship *Buffet* having, on the 29th, crossed the mines several times and made all the alarms speak repeatedly, it was resolved that this vessel should again pass over the mines for the experiments on the 30th, in order to be certain that everything was in order. No. 2 was not made to speak until after being crossed a couple of times, and, after two more vain efforts, No. 7 followed. Then, also, did No. 5 speak, which would not become quiet again afterwards. After having waited about a quarter of an hour for the last-mentioned alarm, we agreed to spring the sleeping mine, as the water was rising and a higher column of water above the mine was thought to be desirable.

The alarms were electrically connected with the alarm-battery and their galvanometers, and the red flag, the signal for the commencement of the experiment, was raised, when all of a sudden alarm No. 3 began to speak, though it had been silent ever since twenty minutes, when the *Buffet* had crossed it for the last time. At this moment the vessel was $\pm$ 560 meters away from No. 3. Having waited some minutes for it to become quiet, the sleeping mine was sprung, which now, on account of the tide coming in (half-tide), lay at a depth of 8.5 meters (the galvanometers of Nos. 3 and 5 still deflecting). The height of the water-column thrown up by it amounted to $\pm$ 14 meters. The springing of the sleeping-mine with 100 kilograms gunpowder had the following effect on the alarms: No. 6, which lay at 12 meters, and No. 5, at 15 meters from the sleeping-mine (of the latter the contacts were already closed before the experiment), had become altogether unfit for use; No. 7, at 20 meters distance, remained useless for 3 minutes 54 seconds; No. 4, at 32 meters, remained useless for 5 minutes 24 seconds. Of No. 3, at a distance of 44 meters, the contacts were already made before the experiment. About 30 seconds after the springing of the mine, it was fit for use again. So it seemed that it had needed this powerful remedy to get into proper order again. No. 2, at a distance of 71 meters, was useless for 30 seconds, at the most, as also No. 1, which lay at 100 meters distance.

When, about a quarter of an hour after the springing of the mine, the *Buffet* again passed over the alarm-mines a few times, Nos. 1, 2, 3, 4, and 7 worked as well as before the experiment.

The mines and alarms then being taken out of the water, they were examined, and the lids and bottoms of mines Nos. 6 and 5 were found to be considerably bent, the lid of No. 6, 59 millimeters, and its bottom 52 millimeters, the lid of No. 5, 90 and its bottom 65 millimeters (of the latter, however, 16 and 4 millimeters were owing to the preceding experiment). For the rest, these mines had remained in good order; their insides proved to be perfectly dry. Their apparatus were found on the bot-

tom of the alarm-globes, some parts of these instruments being deranged, bent, or broken.

Nothing particular was to be noticed in the other mines and alarms, except that the bottoms and lids of mines, Nos. 7, 4, and 3 were a little bent, and that No. 4 had considerably changed in sensibility.

The positions of the alarms after this springing experiment have been taken down in Table A.

Mr. Kaiser thought he could prevent apparatus becoming unfit for use, the mines of which lay at 10 and 15 meters from a springing mine, by making certain parts of the apparatus stronger, and the subcommittee expected a good result from this, considering the way in which the alarms had become useless. Then already did the subcommittee find one drawback in the use of Dr. Kaiser's alarm, viz, that some of the apparatus spoke untimely. Mr. Kaiser ascribed it to the influences of the tide-current on the mines, which, as they had been lying then with the axis of their cylinder in a horizontal direction, could be moved by a weak force, and he believed it could be remedied by placing the mines on their bottoms. He also believed that in this way the time of the vibrations during the springing of a neighboring mine would be diminished.

The subcommittee resolved to have some of the apparatus altered after the directions of Dr. Kaiser (to wit, those four which were going to be laid nearest to the sleeping mine), and to repeat the experiment, as much as possible in the same way, only the mines were to rest with their bottoms on the bottom of the water. In order to be quite safe from any possible magnetic influence of fragments from the mine, sprung before, the alarm-mine to be laid nearest to the spot, where this had taken place, would be kept 100 meters away from it.

The time of delay caused by the repair and alteration of four apparatus was used to put down the other three alarms contained in their mines, in that part of the water which was set apart for the new springing experiment, in order to ascertain whether the alarms really did not speak before their time, when the mines stood on their bottoms.

In order to be able to place the mines with their bottoms on the bottom of the water, a bar was firmly fixed round the side wall of each mine, just a little below the rim on which the lid was fastened. Two long loops, opposite to each other, were bent over the edge of the lid (where they were furnished with leather to prevent fretting) so that they could just touch each other about the middle of the lid. The rope required for the sinking of the mine was then passed through the loops, so that the mine came in a horizontal position under the hoist of the boat.

The mines with alarm No. 2 and 7 have been lying in the water from the 2d to the 15th of August. They were daily tested (between 8 a. m. and 6 p. m.) at every half-tide—it being supposed that then the current was

strongest—and during still water No. 7 was found speaking untimely once; the other two several times. (See Table E.) For the observations of these days, as also for other experiments, these alarms were all through the day and night time in electrical connection with the alarm-battery, as long as they were in proper order. In this way they could, so to say, be *caught* speaking untimely, as the contacts being once closed continued in this state, with a sufficiently strong galvanic battery, until the current was interrupted.

If at any time of the day it was thought necessary that the contacts of some alarm should be made, as the magnet of its galvanometer, which stood on land, was in an undeflected position, the current was interrupted and a moment after made again. Very often the alarm was then found in proper order.

If this was not the case, the galvanometer being deflected again, the current was once more interrupted and closed again a few minutes afterwards. Did the alarm still continue speaking untimely, it was kept out of the circuit till the observation of three hours later, or, if it was in the evening, till the first one of the next day, and not tested until then. It was not connected again to the alarm-battery before it proved to be in proper order.

A few times the exact moment has been known at which an alarm began speaking untimely, *e. g.*, the 17th of June, when, whilst the observers were present in the station, and the alarms were electrically connected to the alarm-battery, the galvanometer of No. 4 was suddenly deflected, and the 30th of July, when Nos. 5 and 3 became useless. During each of these three observations the current passed through the water.

It has not been observed that an alarm began to speak during still water; alarms, speaking untimely, however, were noticed to continue doing so at the surface during still water. With respect to this some observations may be found in Table E.

When the alarm-mines were lifted, the heads of the rivets in the bottom of every mine were noticed to be rather bright; from this circumstance we concluded that the mines had been standing in the water on their bottoms, more so, as the paint, with which the side walls had been covered the day before, was not in the least damaged.

The examination of the alarms after the mines had been lifted did not give rise to any particular observations; all of them worked satisfactorily. Now, also, Mr. Kaiser adhered to this conclusion drawn before, that submarine currents or other external influences on the bodies of the mines must be the cause of the untimely speaking. He did not think it possible that the cause had to be looked for in the apparatus themselves, as on land nothing of the sort ever happened during all the weeks and months he examined them, though at that time already it had been observed that alarms continued speaking also at the turning of the tides, the subcommittee had no sufficient foundation for absolutely opposing Dr. Kaiser's

opinion, and they could in no other way account for the untimely betraying.

The 18th of August Mr. Kaiser came to Texel to place the four apparatus which had been modified in the way proposed by him in the globes, and to improve their position, if necessary (which he had tested at Leiden), and furthermore to clean and, if required, to regulate anew the apparatus which had been lying in the water of late. (For the position of the alarms *vide* Table B.)

The position of No. 2 had to be changed seven times before its sensibility was satisfactorily regulated. Those mines with alarms which were quite ready were tested before being placed in the water. Not all the alarms were this time inclosed in the mines with corresponding numbers. We wanted to place those mines which had been bent least from the preceding springing experiment nearest to the sleeping mine, and in them to put the four alarms which had been modified and made stronger, so that alarm No. 2 came in mine No. 4, No. 4 in mine 2, No. 7 in mine 6, No. 6 in mine 7, whilst the rest of the alarms were placed in their corresponding mines.

On the 20th of August three alarm-mines were put in the water, and on the 22d the rest, and also the sleeping mine. (See plate opposite.) Only one alarm spoke untimely between the 20th and 27th of August, the day when the springing experiment was made. (See Table E.) On this last-named day the subcommittee assembled at Oude-Schild. Mr. Kaiser was not quite well, so he could not attend. In the course of the afternoon of that day H. M. Buffet crossed the line of torpedoes several times. All the alarms repeatedly betrayed her presence. In the afternoon the iron sleeping mine was fired.

The springing of this mine of 100 kilograms gunpowder, lying at a depth of 7 meters, and throwing up a column of water, the highest point of which reached to 26.2 meters, had the following effect on the alarms:

No. 6, whose mine was nearly 101 meters away from the sleeping mine, had not, or at least not notably, moved; No. 1, whose mine lay nearly 10 meters distant from the sleeping mine, had become useless.

No. 2, and the others, whose mines lay at a distance respectively of 15.5, ± 22 , 29, 45, and 67 meters, spoke during the explosion, but within one minute after they all got at rest again. When about a quarter of an hour after the experiment the Buffet passed over the mines, all the alarms, except No. 1, worked as well as before the experiment. A couple of hours later, when the ebb current was passing over the mines, the Buffet fired a shot from one of her 23 centimeter cannons with the great charge and a cartridge. At the moment the shot was fired, alarm No. 2, which a few seconds before had betrayed the presence of the Buffet, had just become

Experiments on the 17th, 18th & 19th of September 1873
 on the way of crossing experiments.

Experiment on the 27th of August 1873
(3rd springing experiment)

Horizontal projection of the position of the mines
V VI
V VII IV III

Alarm mine V at a depth of 8.2 metres distance from the iron sleeping mine 20.83 M.

I	8.3	9.68
II	8.2	15.54
VII	8.3	29.34
IV	7.6	44.75
III	8.4	67.10
VII	6.7	100.8
Iron mine	7.5	

NB The depths of the water are stated in metres during low water
(1 metre under high sea)

Horizontal section of alarm mine No 1
two decimetres below the upper rim, before
and after the springing experiment of
August the 27th 1873
(at 3 of its real size)

quiet, and the turret-ship was with her bow nearly 8 meters away from the vertical projection of this apparatus.

None of the alarms got into motion by the firing. When the mines and alarms were examined, on being taken out of the water, it was found that the bottom of mine No. 1 was bent 55 millimeters, and its lid or cover 90 millimeters. The cylindrical side-wall was crushed in eight different places between the lid and the interior wall (partition), in one place as much as 52 millimeters.

The plate gives a section of the mine as it was before and after the experiment. This section has been made about 2 decimeters from and parallel to the lid. The deformation was greatest there. Between the interior wall and the bottom, the wall of the mine was not bent. The brass angle-bars had retained their shape; they were slightly bent about where the long loops were, that served in paying out the mines.

On opening the mines, a little water was found to have got in them. A few of the cartridges, which were filled with sand and sawdust, had become hard from the damp; the rest were dry. The water had penetrated the mines along the stuffing-boxes, whose outside caoutchouc rings had been broken by the pressure of the water on the lid when the sleeping mine was sprung.

The conducting wire of the piece of cable of the alarm was broken in the mine, in consequence of this piece of cable being squeezed between the sharp edge of the nut belonging to one of the stuffing-boxes and a cartridge, which squeezing was also caused by the bending of the lid of the mine during the explosion. When this piece of cable had been cut through in the place of rupture, and then the part of it which is connected with the alarm had been attached to one of the poles of the alarm-battery, the other pole being in the electrical connection with the alarm-globe, the apparatus worked properly, when a magnetic bar was held near it (the alarm-globe was still placed in the mine, and nothing further had been changed). Afterwards, however, on examining the alarm with the comparator, its sensibility proved to have changed considerably. The bottom and lid of mine No. 2 were bent about 50 centimeters. The edge of the mine and the lid, too, was very much bent all over the extent of a chord of 25 centimeters to a maximum of 20 millimeters.

The cylindrical side-wall was bent over a small surface. As mines Nos. 1 and 2 were sent to Amsterdam for repair, the apparatus No. 4 was also taken out of the latter. It was tested all right; its sensibility had changed only very slightly. (See Table B.) The other mines were not opened, as nothing particular was noticed in them, except that they were slightly bent. The alarms were tested and found in order.

The results obtained from the last springing-experiment proved, in the opinion of the subcommittee, that Mr. Kaiser's modifications of the alarms

had been improvements ; for, in their opinion, it may be taken for granted that an alarm, lying at a distance of 15 meters from a mine with a charge of 100 kilograms gunpowder, and at a depth of 7 or 8 meters, will properly resume its work one minute after the springing of this mine.

That the influence of the vibrations on the apparatus lasted a shorter time is owing to the firmer position of the mines on the bottom of the water. This seemed to be brought about at the expense of the mines themselves, which were much more damaged now than in consequence of the first springing experiments, when the bottoms and lids only were a little bent.

Though the results of the springing-experiments with sleeping-mines of 100 kilograms gunpowder were of a nature to justify similar experiments with mines of a greater charge, the subcommittee could not undertake them, the alarm mines not being strong enough, so they agreed to solve the question whether it is possible to regulate the alarms in such a way that they will, when placed on the bottom of some water, as well betray at a favorable moment the presence of a large iron-clad as of a small one.

Considering the relatively short time which remained before the commencement of the unfavorable season the subcommittee, after consulting Mr. Kaiser, thought it better not to treat this question in the way set down in the programme of the experiments, viz, by passing with a monitor first over one mine only, which was successively placed at various increasing depths, but they resolved to look at the question in another way, which would not take up so much time, viz, to begin with ascertaining whether an average position could be found for three iron-clads of different magnetic power at the same depth.

There were no drawbacks in the modification of the course of experiments, as at any rate his excellency the minister of the navy's permission had to be asked for the disposal of one of the monitors lying in the southern harbors, as two turret-ships were in the waters of the position Helder-
Texel for summer manœuvres.

For the series of experiments to be made now, the mines were going to be laid in a direction about perpendicular to the coast-line or to the current, so as to facilitate the crossing of iron-clads. In such a direction we tried to find a line of about 75 meters length, in which the depths varied at the most between 6 and 8 meters, in order to place at distances of 15 meters the six alarms, which retained their position of the previous experiment, to betray a monitor at a depth of ± 7 meters at a given moment. As we have mentioned before, the sensibility of the seventh alarm (No. 1) had changed too much to allow of this apparatus being used unaltered. On account of Mr. Kaiser's illness it could not be modified by him in time.

A line answering to the conditions stated was found to the southeast of

the southern torpedo station. The water near this line was sounded, and the buoys were laid required for the fastening of the boat, which was to put out the mines and for facilitating the maneuvers of crossing vessels. On land six beacons were placed, two of which marked the direction in which the mines were going to be laid. The plate opposite represents the positions of the mines, buoys, beacons, &c. The buoys *c* and *d*, which with *a*, *b*, *g*, and *h* had been used to fasten the steamboat, were removed after the placing of the mines. The buoys *e* and *f* served principally to point out to the iron-clads the boundaries within which the mines lay. By measuring at a guess the distances at which we were from some buoy, when we were not too far away from the torpedo line, these ships could be made to pass over any mine pretty nearly at will. It was known that the two buoys were 170 meters apart from one another, and that buoy *C* lay about 40 meters distant from No. 7, and buoy *f* about 55 meters from alarm No. 2. So a signal sent from the torpedo station to pass over the southern, central, or northern mines could, as a rule, be followed up. (For the crossing experiments of October a definite mine was signaled.) The mines were laid during still water so as to have them as exactly as possible in the places desired. In this manner one boat could put out two mines a day at the most. The rough weather during the first half of September, however, was the cause that these arrangements could not be got through before the 11th, as we could only place one mine on each day, except on the 6th of that month, when the placing of the mines was commenced with.

However, the experiments were not delayed by this, as the turret-ships and monitors were stationed at Flushing and Brielle, and could not be disposed of before the middle of September.

The mines were tested before being put in the water; all the alarms worked properly.

Just as for the previous experiment, the mines were placed so as probably to rest with their bottoms on the bottom of the water. Every day they were observed during still water, and when the tides were strongest (half-tide, according to the Enkhuizen almanac), the alarms, as long as they were in order, were night and day in the electrical connection with the alarm battery. (For the untimely speaking of the alarms, *vide*, Table E.)

September 15th H. M. monitor Tiger was going to steam over the alarms, but it had to be put off to the 17th, as, on account of the high sea of the 15th, the steamboat could not open the communication of the shore with the monitor for agreeing on the necessary signals, and as also the next day the weather was very rough. On the 17th H. M. Tiger passed ten times over the line of the alarms, three times from northeast and seven times from southwest. Excepting twice, when the monitor passed too much

east from the alarms, one or two of them always spoke when part of the keel had passed the line of the alarms. H. M. Buffel, which on the 18th steamed over the alarms, ten times from the northeast and seven times from the southwest, was betrayed fifteen times when part of her keel had passed the torpedo line; once it occurred before part of the ship had passed the line, and once she passed this line too much to the west.

For H. M. Scorpion the alarms were regulated with too great sensibility. Of the twenty-one times this ship passed over the alarms on the 19th of September her presence was betrayed twenty times, ten of which before the ship had passed the line. Once she passed too much to the east, for which reason none of the alarms could speak. During the crossing of H. M. Scorpion she was repeatedly observed to make the alarms speak sooner when coming from the northeast than from the southwest. Of this phenomenon, which was so strongly marked then, little was noticed during the further experiments.

The plates opposite show in black lines with arrows the length of the vessels and the position of their keels with respect to the alarms at the moment they spoke.

For each observation the height of the water over the alarm which spoke has been marked on the drawing. Regarding the way in which the position of the ships with respect to the alarms was ascertained, and the degree of exactness of the observations, the following details may find a place here:

The mines with alarms lay in the direction of two beacons, put up in the neighborhood of Station B about perpendicular to the coast line. One or more flags raised at this station were the signal for the commencement of each experiment. A moment after it was signaled also from this station over which mines, the northern, central, or southern, the ship was desired to pass. By the time she had come to within about a couple of hundred meters from the torpedo line they began at the stations A and B to follow the flag on the stern of the ship with the bearing instruments. At the moment some alarm spoke the person who observed at A the galvanometer called out "stop." All the flags were then struck on board the ship, her course was carefully determined according to the compass; at station A the needle of the bearing instrument was no longer moved, and to station B the letter S was telegraphed.

On hearing the motion of the receiving apparatus at B the observer there also stopped his bearing instrument. It was found that between the moment at which "stop" was called at A and that in which the observer at B stopped his instrument, 1.5 seconds on an average elapsed. This difference was taken into account on the 18th and 19th, and for all further experiments. In order to learn the influence of this difference on the bearing of the vessel it was generally ascertained from two observations at B after

Scale of flectors.

15th September 1873

Monitor Tigger

Greatest length 56.98 M.

width 13.41 "

at stern 2.67 "

Drumstel { at stern 2.83 "

By 1st & 2nd VII 71 flectors water above VII

1st VI 7.2 " " " VI

1st V 6.9 " " " V

By 1st III 6.3 flectors water above III

2nd & 3rd III 7.0 " " " III

1st II 7.8 " " " II

The Roman figures mark the numbers of the mines. Mines VII, VI, V, IV, III, II contain respectively the apparatus VI, VII, V, II, III & IV.

18th September 1873.

North Declin.

Scale

5 4 3 2 1 0 5 10 15 20 25 30 35 40 45 Metres

18th September 1873

Turret - Ship „Büffel“

Greatest length 62.43 Metres

Greatest width 12.19 .

Draught at the stern 4.45 .

Draught at the stem 4.42 .

By 1st VII. 7.1 Metres water above VII. By 1st VI. 7.2 Metres water above VI. By 1st V. 7.5 Metres water above V. By 1st IV. 7.6 Metres water above IV. By 1st & 2nd III. 6.7 Metres water above III.

• 2nd VII 6.7 . . . VII. • 2nd & 3rd VI 6.8 . . . VI. • 2nd V. 7.3 Metres water above V. • 2nd IV. 7.8 . . . IV.
• 3rd V. 7.1 Metres water above V. • 3rd IV. 7.7 . . . IV.

• 4th IV 7.5 . . . IV.

By 1st II 8.1 Metres water above II .

• 2nd II 8.0 . . . II.

The Roman figures mark the number of the mines, Mine VII contains apparatus VI, Mine VI apparatus VII, Mine IV apparatus II, Mine II apparatus IV. Mines V and III contain apparatus of corresponding numbers.

each crossing experiment, how many minutes the needle of the bearing instrument went round during those 1.5 seconds under the same circumstances of course and velocity of the vessel.

Mostly the ships finished their length in 20 to 30 seconds. Now, if we allow a play of 1 second for the above 1.5, a mistake of a couple of meters may have crept in.

To represent in drawing the results of the crossing experiments of September and of the 8th October, use was made of the corrected courses observed on board for the Scorpion and the Tiger, and of the uncorrected courses for the Buffet, because the corrected ones of this vessel could not be trusted (relied on).

When the courses of the Scorpion and the Tiger, determined with the compass and corrected with regard to the duration and declination in the ordinary way, were compared with those of the other vessels observed at the very same time by means of a pelorus, a difference was marked, amounting to 27 inches for the Scorpion and 12 inches for the Tiger. (A pelorus is a planchet of the form of a rose; and, like this, divided in points. A flat ruler can turn round in its center. By measuring with this instrument the angle made by the direction in which a certain object is known to lie and the keel of a ship, it is easy to find, after a simple calculation, the direction of the keel or the course of the ship.)

For representing in drawing the other results, of the 9th, 10th, and 11th of October, use has been made of the courses of the ships as ascertained with the pelorus. This manner of making observations is, in general, probably more correct, because we can then dispense with the mariner's compasses with their inaccuracies.

The subcommittee resolved, in their meeting of September 20, to repeat the last experiments with alarms regulated less delicately. Mr. Kaiser thought himself able to place these instruments in a position that they should at a given moment betray the presence of the Scorpion without losing the good quality they had proved to possess, viz, of betraying H. M. monitor Tiger at a proper moment.

In order to find the necessary degree of sensibility in the quickest way possible, they were not going to be regulated equally delicately, but three of them a little more than those used for the last experiments, the next three more still, and the seventh more again than the rest. That very day mines Nos. 2 and 3 with alarms Nos. 4 and 3 were lifted, and the 22d all the other alarms were taken out of the water. (For the positions of the alarms on this last-mentioned day, *vide* Table B.)

When the positions of the alarms were being controlled, it was surprising how soon, especially No. 3, which had spoken untimely so often before, became quiet when for some reason or other it was moved from its place or taken up. A smart push had to be given to it before its galvan-

ometer was deflected. The globe, too, could be brought into a slow swinging motion without making the alarm speak, and even the whole apparatus could be turned round the fourth part of a circle without any visible effect on its galvanometer. This same alarm was found speaking untimely on the 16th September, after having been at rest for six days; it was after a stormy night it is true, but none of the others had spoken.

The sensibility of this apparatus had not changed materially by the springing of the sleeping mine on the 27th of August, and by the laying and lifting of its mine for this springing experiment and for the experiments of the 17th till 19th of September.

During the experiments in September, mine No. 4, containing alarm No. 2, had as a rule betrayed the ships much sooner than the other ones. As the position, too, of this alarm had changed but little (*vide* Table B), no other explanation could be found for the alarm's speaking so much sooner but that some iron object must have been lying in its neighborhood. As we wanted to know whether this phenomenon would repeat itself, we resolved to place the mines for the next experiments—those of October—exactly on the same spot where they had lain during the last crossing experiments; but in order to save alarm No. 4, the most important one, from the influence which had perhaps affected alarm No. 2, it was going to be placed at one of the ends. These experiments, however, did not clear up the matter. In alarm No. 5 nothing particular was noticed; No. 3 was by far the most sensible, but on examination after being lifted its position proved to be considerably changed. (See Table C.)

The sensibility of alarms Nos. 6 and 7 had greatly altered between the 18th August, when they had been regulated again for the last time, and the 22d of September (see Table B); the position of the rest had remained about the same all that time, except of No. 1, which had most probably lost its original position entirely by the springing of the sleeping mine.

In the afternoon of September 22 all the alarms were sent to Leiden to be regulated by Mr. Kaiser. On the 2d October they were again received at Oude-Schild. The apparatus had before been sent from Leiden in a box, so that they should have less danger of being damaged on the journey, and then been placed in their globes in Texel by Mr. Kaiser. This could not be done now, on account of Mr. Kaiser's illness; so the alarms were got entirely ready at Leiden. A trusty person, a second mate in the navy, was charged to take it to Amsterdam by goods-boat, and to Nieuwediep by barge. Their positions were then tested by the two members of the subcommittee who were staying in Texel.

Up till now the alarms had always been kept closed up in their globes for examination with the comparator. In order to be still able to do this, now they were less sensible, the magnetic bar of the comparator was made 2.2 times stronger.

Experiments on the 8th, 9th, 10th and 11th of October 1873
2nd Series of crossing-experiments.

10th of October 1873
Greatest length 62.5 metres
Greatest breadth 11.53 "
Draught { at the stem 4.58 metres
 at the stern 4.75

10th of October 1873

circumference 0.25 metres

greatest breadth 1153

Draught { at the stem 4.58 metres
at the stern 4.75

North Declination.

Scale

5 10 15 20 25 30 35 40 45 50 Metres.

Monitor Tiger

9th 11th October 1873.

Greatest length 56.98 metres

Greatest breadth 13.41 .

Draught at the stern 2.67 .

Draught at the stern 2.63 .

Correctness of observation 1st II uncertain.

By 1st II IV (alarm not speaking) 7.4 N water above IV.

3rd (alarm speaking) 7.0 .

4th (mine not speaking) 7.5 .

1st VII 7.9 Metres water above VII

3rd 7.5 .

4th 7.4 .

5th 7.2 .

1st VI 7.4 .

2nd 7.3 .

3rd 7.2 .

4th 7.1 .

5th 7.2 .

6th 7.0 .

7th 7.6 .

1st V 7.9 .

3rd V 7.5 .

1st II 7.6 .

2nd I 7.7 .

3rd I 7.7 .

apparatus not speaking)
V 7.9 water above VII
II
I 7.8
(mine not speaking)

Eber

11th 10th October 1873

Greatest length 26 metres

Draught at the stern 2.0 .

at the stern 1.75 .

Five or the 6 times that the Eber tried to cross mine I II and III, mine III spoke
One or the 5 times that it was tried to cross mine III, this mine spoke
During these experiments there was 8.2 M water above mine III 8.7 M above
mine I and 8.3 M above mine II

9th 10th October alarm No III useless. Series containing mines I II and III regulated the most sensible, the
Series containing V VI and VII a little less and the Series mine IV the most sensible
Crossed 25 times without making any apparatus speak (12 times of which on trying to pass over IV)
The arrows near 1, 2, 4 IV and 3 VI show where the stern has been in 4 crossings when mine of the alarm spoke
The arrow and the dotted line near 7 VI show the place where the stern has been and the direction
in which the ship has been lying on occasions of one of the crossings when mine of the alarm spoke

The positions the alarms had on being sent from Leiden and those they proved to have at Oude-Schild when tested with the strengthened comparator are stated down in Table C.

In order to facilitate the comparison between these positions and the previous ones, Table D shows the positions which the alarms had at Leiden, according to the stronger comparator, by the side of those Mr. Kaiser thought they would have had if observed with the original comparator.

As the difference in the sensibility of the north and the south pole of alarm No. 5 was too great, and its south pole was found to be too sensible, those members of the subcommittee who were staying in Texel changed its position, Mr. Kaiser having given permission to do so.

Nothing was altered in the other alarms (for the positions, *vide* Table C). The mines were all filled and got ready on the 2d and 3d of October. Each alarm was now placed in its corresponding mine. On the same days they were all verified and found to be in order.

Just as for the preceding experiment, the mines were let down during still water and in such a way that they could safely be thought to rest with their bottom sides on the bottom of the water (Plate 10). Still, during the time they lay in the water, from the 2d to the 14th of October, it occurred repeatedly that they betrayed before their time. (*Vide* Table E.)

Only the three least insensible alarms spoke untimely. On the 18th of October the Buffel passed thirty-three times over the line of the mines; on the 10th, the Scorpion forty-one times, and on the 9th and 11th, the Tiger forty-six times. For the results see plates opposite.

In order to make the depths of the water over the different mines as equal as possible, the ships crossed on the 9th of October and following days, as a rule, the least deep alarm-mines during high tide; the other ones during low tide. For the rest the experiments were made in the same manner as in September.

The naval board of directors at Willemsoord happened just then to be making proof-trials with H. M. gunboat Ever, of the newly-adopted staunch type, and from this circumstance we profited by making this vessel too pass over the least insensible alarms. When on the 11th October this ship went a few times across the series of alarms Nos. 1, 2, 3, it happened repeatedly that No. 3 spoke, which was afterwards found by means of the comparator to be more sensible than the other ones. When afterwards H. M. Ever was made to pass over this mine several times, in a direction almost perpendicular to the torpedo-line, it was observed that No. 3 spoke. This observation is represented on Plate B.

In the opinion of the subcommittee the alarms Nos. 1, 2, and 3 were too sensible for the Scorpion, and No. 4 was too insensible for the Tiger. According to the results obtained with the alarms Nos. 5, 6, and 7, they

think it very probable that Dr. Kaiser's alarms can be made for practical use sufficiently accurate to betray, at a given moment, and at a depth of 7 or 8 meters, the presence of the two turret-ships *Buffet* and *Scorpion*, as well as of the monitor *Tiger*. It is true alarm No. 7 spoke twice when the stem of the *Scorpion* was still a couple of meters away from the torpedo-line, but some time will always elapse between the moments of the betraying and the firing of a mine, so this is no drawback. Besides the circle of destruction of the torpedoes may be taken into account. From this the subcommittee concludes that alarm No. 7 would also work properly in the case of a vessel like the *Scorpion*.

Once alarm No. 6 did not speak when the *Tiger* went past it at a short distance. The subcommittee thinks this a fault which may very likely be remedied by placing the mines a few meters nearer together. It is not improbable that during the experiment the *Tiger* passed just between the alarms Nos. 6 and 7, which lay 15 meters apart from one another.

Of the dotted line it may be taken for granted that the arrow, the stem of the ship, is pretty exactly in its proper place, but the line marking the course may be a little wrong, and this need be only very little to cause a relatively great difference in the place of this line with respect to the alarm. However, according to Mr. Kaiser, alarms in the positions which Nos. 5, 6, and 7 had during the last experiments, would pretty nearly answer the object we have in view, viz, the betraying of the three vessels at a favorable moment. In order to reach this object under all circumstances, he thought that the mines would have to be placed one or two meters nearer to each other, and that the alarms would have to be regulated a little more delicately, which, in his opinion, would not be an obstacle against the betraying at a proper time of the *Scorpion*, and an improvement for vessels like the *Tiger*.

The results of the necessary inquiries into the practical advantages of Dr. Kaiser's magneto-galvanic torpedo-alarm may be called favorable in the opinion of the subcommittee only for as far as these inquiries refer to the programme of experiments which they were charged to make. An alarm has proved not to speak untimely when at a short distance from it a shot with ball is fired from a heavy gun placed in a coast battery or on board a ship; it will probably not be damaged, but not able to work for a few minutes, when it is contained in a mine at 15 meters distance from a springing mine loaded with 100 kilograms gunpowder, both mines lying at a depth of 7 or 8 meters; and, lastly, it is most probable that a position can be given to them in which at a depth of 7 or 8 meters they will at a favorable moment betray the presence of H. M. turret-ships *Scorpion* and *Buffet* as well as of H. M. monitor *Tiger*.

To these results are opposed a couple of great drawbacks of Dr. Kaiser's alarms, which have come to light in the course of the experiments. First

of all the change of sensibility of apparatus which had been at work some time and whose position had not been altered; and, secondly, their being repeatedly found speaking untimely in the waters of Texel, when all of them were lying in the water for a shorter or longer time.

As for the first drawback, Table B may show how Nos. 6 and 7, between the 18th August and the 22d September, materially changed their position.

In the same way it may be gathered from Tables A and C, that especially Nos. 3 and 5 have repeatedly suffered from their transport from Leiden to Texel, whilst also the sensibility of No. 3 had undergone a considerable change between the 2d and 12th October, when it was lying in the water for the last experiments. Mr. Kaiser thinks he will be able to remedy this by decreasing the number of screws in the apparatus, by soldering as far as possible those screws which must necessarily remain, and by giving a fixed position to the alarms when being transported.

The subcommittee dares not undertake to judge to what extent he will succeed in improving his invention, less so because some of the alarms have repeatedly been in a condition in which they gave proofs of great solidity, however delicate the apparatus looked. For more than once did Mr. Kaiser, in the presence of the members of the subcommittee, shake some alarm with great violence, which did not influence the sensibility of the apparatus. Once, on the 31st of July, did the steamboat, when bringing on land mine No. 2, strike pretty strongly with its hoist against a dredging-machine working in the neighborhood and very much hindering its maneuvers. As the mine was hanging on this hoist, it got squeezed in so that its side-wall was bent rather considerably, we guessed about half a decimeter. Notwithstanding this, the alarm did not only work just as well as before the mine lay in the water, but even its sensibility proved to have changed about nothing ever since the 16th July. (*Vide* Table A.)

Perhaps the soundness of the alarms has been proved more clearly still by the fact that an alarm remained fit for use after the great pressure during the springing of a neighboring sleeping mine.

As it has been mentioned already, Mr. Kaiser ascribes the untimely speaking of apparatus to motion of the mines, either in consequence of the current or of some other cause unknown to him. The subcommittee has not yet found sufficient reasons for ascribing the untimely betraying to the influence of the current on the mine. Even if they take it for granted that the currents at the bottom do not correspond with those at the surface of the Texel water, this can, in their opinion, make little difference to the matter, as some alarms were found speaking untimely, not only for hours but sometimes during all the observations for days running. Besides, at the hours fixed for the observation of the alarms lying in the

water they were repeatedly, amongst others during the last crossing experiments, observed for some hours running with intervals of a few minutes. Of course in this way several observations were obtained during the going out and coming in of the tides; but for these various circumstances no telling difference was noticed in the condition of the alarms. However, it happened more frequently that alarms which spoke untimely were found at rest during still water than when the current was in full force. They also spoke more frequently untimely when they had just been laid in the water, or after a few days, than after a week or longer.

The following observations may perhaps speak in favor of the supposition that squeezing or fretting of some parts of the instruments should be taken into account when an inquiry is made into the continued untimely speaking of alarms which have become useless for a time.

As it has been mentioned already, alarm No. 2 was on the 30th of July found in order a few seconds after the springing of a sleeping-mine, whilst a few minutes before it was noticed to be useless. No. 3, which became unfit for use the 8th of October, and was found speaking untimely after all the observations of that day and the next until 2 o'clock in the afternoon, got into proper order again at that hour during still water during the crossing experiments with the Buffet. This same No. 3, which again refused to work on the 9th of October, suddenly got into order again on the 10th at a quarter past one, also during still water, just when the Scorpion had steamed over the mines, and just at a moment when its services were going to be required for the experiments. A signal had been sent to the Scorpion to pass over alarm-mine No. 5; the cable of No. 3 had been detached from the battery. None of the alarms spoke. When, immediately afterwards, the cable of No. 3 was connected with the battery, the alarm was found to be in order. A few minutes earlier, when an observation was made, its galvanometer was deflected before its time. During the other three days it lay in the water it remained in proper order. Considering all this, the subcommittee thinks the question of the untimely speaking of alarms to be altogether unsolved.

The change of their sensibility, too, continues to be a point for examination. In the beginning of November the alarms, inclosed in their mines, were laid in one of the canals of the naval dock-yard at Amsterdam to examine whether they would also speak untimely in this nearly stagnant water, with a soft, muddy bottom.

If it appears from this experiment that the alarms do not speak untimely after lying in the water for several weeks it is the opinion of the sub-committee that these instruments, improved according to the instructions of Mr. Kaiser, should be inclosed in mines with a greater base and of a better shape for resisting water that is brought into motion

by some cause or other. (Up to the 29th of December the alarms were in a proper state.)

On account of the many obstacles which will have to be surmounted before the alarms in all respects will prove to be of practical use, the subcommittee venture to make the observation that, in case the experiments with the alarms should be resumed, they think it advisable at the same time to commence other experiments—in the first place with those which may lead the way to the application of offensive torpedoes.

December the 29th, 1873.

The Torpedo Subcommittee:

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Major-General, President.

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Capt., Royal Artillery.

TABLE A.—*Positions in which the alarms were found.*

No. of alarm.	Ready May 15 for experiment of May 26 (first firing experiment).		Ready May 29 for experiment of May 30 (second firing experiment). ^a		Ready June 12 for experiment of June 19 (first springing experiment). ^b		June 19, 20, after the experiment of June 19 (first springing experiment).	
	N. P. comp.	S. P. comp.	N. P. comp.	S. P. comp.	N. P. comp.	S. P. comp.	N. P. comp.	S. P. comp.
1	31	32	31	32	27	30	.....	.....
2	31	30	.....	.....	29	32	30.5	32.5
3	30	30	.....	.....	32	38	.....	.....
4	30	30.5	30	30.5	27	29	(c)	(c)
5	29.5	29.5	48	75	26	30	(c)	(c)
6	.....	.....	.....	.....	.....	.....	.....	.....
7	28	29	42	51	27	31	(c)	(c)

^a Alarms Nos. 1 and 4 had not been regulated anew.

^b All the alarms were again regulated; No. 3 has not been in the water; was found useless June 13; already; No. — has become useless while being in the water.

^c Unfit for use by springing of sleeping mine.

TABLE A.—*Positions in which the alarms were found*—Continued.

No. of alarm.	July 14, on forwarding from Leiden. ^c		July 16, on arrival at Oude-Schild.		July 16, on having altered their position and ready for the experiment of July 30 (second springing experiment). ^d		July 31 and August 1, being lifted, the experiment of July 30 being over (second springing experiment). ^e	
	N. P. comp.	S. P. comp.	N. P. comp.	S. P. comp.	N. P. comp.	S. P. comp.	N. P. comp.	S. P. comp.
1	29	31	29	28	29	28	30	22
2	29	29	31	30	31	30	30	29
3	33	28	26	18	29	30	27	30
4	31	30	32	31	32	31	29	48
5	31	31	34	28	{ 34 31 34 }	{ 28 32 28 }	(c)	(c)
6	31	29	31	28	31	28	(c)	(c)
7	32	31	30	32	30	32	31	32

^c Unfit for use by springing of sleeping mine.

^d The alarms were all regulated anew.

^e Alarm No. 3 only was regulated again.

^f Examination of No. 4 an hour afterwards showed N. P. comp. 29 centimeters; S. P. 63 centimeters.

TABLE B.—*Positions in which the alarms were found.*

No. of alarm.	Ready August 18 for the experiment of August 27. (third springing experiment). ^a		Lifted September 3, the experiment of August 27 being over (third springing experiment).		Ready for experiments of September 17, 18, and 19. (first crossing experiments). ^b		Lifted September 20 and 22, after the experiments of September 17, 18, and 19. (first crossing experiments). ^c	
	N. P. comp.	S. P. comp.	N. P. comp.	S. P. comp.	N. P. comp.	S. P. comp.	N. P. comp.	S. P. comp.
	cm.	cm.	cm.	cm.			cm.	cm.
1	36	33	24	105	{ Not used. The others were not taken out of the mines. So see positions of August 18. }		{ 25 33 }	64 Sept. 20 42 Sept. 22
2	30	30	(d)	(d)			29	33
3	28	34	(d)	(d)			28	32
4	33	29	{ 37 34 }	{ 28 30 }			30	30
5	29	30	(d)	(d)			32	31
6	30	29	(d)	(d)			27	24
7	29	25	(d)	(d)			26	41

^a Alarms were cleaned; all were regulated anew.

^b Alarms had been again regulated for the last time August 18.

^c Alarms had been regulated anew for the last time August 18, nor had any alteration been made in the position of No. 1.

^d Mine not opened.

N. B.—The numbers stated in these tables A and B mark the distances in centimeters from the center of the alarm apparatus to one of the poles of the magnetic bar of the comparator at the moment an alarm began to speak. (In order to be able at a favorable moment to betray a monitor at a depth of ± 7 meters, this distance must be somewhere about 32 centimeters.)

TABLE C.—*Positions in which the alarms were found.*

No. of alarm.	September 29, on forwarding from Leiden.		October 2, on arriving at Oude-Schild.		Ready October 3, for the ex- periment of Oc- tober 8-11 (second series of crossing experiments).*		Lifted October 14, the exper- iments of Oc- tober 8-11 being over second se- ries of cross- ing experim'ts).		November 14, after be- ing sent from Texel to Amsterdam.	
	N. P. comp.	S. P. comp.	N. P. comp.	S. P. comp.	N. P. comp.	S. P. comp.	N. P. comp.	S. P. comp.	N. P. comp.	S. P. comp.
	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.
1	39	39	36	39	36	39	37	38	33	42
2	36	37	37	35	37	35	36	34	33	37
3	34	34	40	35	40	35	47	30	36	34
4	25	23	24	23	24	23	23	25	23	24
5	30	28	34	27	32	28	32	27	30.5	29
6	28	28	31	27	31	27	30	29	29	30.5
7	29	28	29	31	29	31	31	30	29	34

* Alarm No. 5 only had been regulated anew.

N. B.—The numbers stated in this table mark the distances in centimeters from the center of the alarm apparatus to one of the poles of the magnetic bar of the comparator, which was 2.2 times stronger than before at the moment an alarm began to speak.

TABLE D.—*Comparison between the positions of the alarms, ascertained with the comparator and with the 2.2 times stronger comparator.*

No. of alarm.	Comparator.		Stronger compara- tor.	
	N. P.	S. P.	N. P.	S. P.
1	24	26	36	39
2	24	25	36	37
3	25	23	34	34
4	17	15	25	23
5	20	19	30	28
6	19	19	28	28
7	19	20	29	28

TABLE E.—Table of the untimely speaking of alarms.

No. of alarm.	Laid in the water and found in order.	Found speaking untimely.	Current noticed when some alarm spoke untimely.	Condition of the weather when some alarm was found to speak untimely.	When lifted and found in what state.	Remarks.
1	1873. May 16.....	May 17. At 2 in the afternoon and during all further experiments of that day. May 19. Between 10 and 11 a. m. several times. However, it got repeatedly into proper order again for some minutes. (In the morning it was found in good order.) May 20. Several times; got into order when the wind began to fall. May 21. After 1 p. m. when the current was strongest. (Remained in order the 22d; also at the hours when with little wind a continual ebb current passed through the water. May 23. Was in order at 8 a. m., but later on in the morning, at increase of wind and current, it began repeatedly to speak untimely. Got into order again at 12 30, and remained in good condition during the rest of the days experiments were made with it, though there was sometimes a strong current whilst it was tested.	Strong ebb..... Strong flood Flood Ebb (low water at 2.30.)	East wind; reefed top-sail breeze. (See note p. III of this table.) Northwest wind; top-sail and reefed top-sail breeze; high sea. Northwest wind; top-gallant gale decreasing to soft breeze. Southwest wind; top-gallant gale. Southwest wind; top-gallant gale increasing to hard top-gallant gale.		The alarms which have been lying in the water between May 16 and 19 were regulated so as to betray a monitor in + 7 meters depth of water. The two alarms which have been in the water from May 29 to 30 were regulated as sensibly as possible.
2	{ May 16 { May 21 }	May 19 and 21. (When it was taken out of the water) in all the observations.			{ May 21, in proper order. May 28, same May 28, in proper order. May 28, in proper order. May 27, in proper order. May 30, in proper order.	
3	May 16					
4	May 23.....					
5	{ May 23..... { May 29 }	Immediately after its being put in the water, on the 29th of May, its contacts were sure to be closed. (It was exceedingly sensible and practically useless). All the time it was lying in the water the apparatus did not get into order.				
6	Not used.....					

7	May 24.....				May 27, in proper order.	
	May 29.....				May 30, in proper order.	
1	June 13.....				June 19, in proper order.	June 16, in No. 2, a contact through which a galvanic current could pass. This contact continued till the alarm had been lifted.
2	June 13.....	June 14. In the afternoon a few times, for a short time.	Strong ebb.....	Changing wind; soft breeze.	June 14, in proper order.	
3	Not used.....					
4	June 14.....	June 17, 2.50 p. m. Continued speaking untimely for 1 or 2 minutes.	Ebb.....	Changing wind; soft breeze.	June 19, unfit for use by springing of sleeping mine.	The alarms were regulated to betray a monitor in $\pm$ 7 meters water.
5	June 14, a. m.....	June 14, a. m. A few times, for a short time.	Strong ebb.....	Changing wind; soft breeze.	June 19, the same.	
6	Not used.....					
7	June 10.....				June 19, the same.	
1	July 21.....				July 28, in proper order.	
2	July 17.....				July 31, in proper order.	
3	July 21.....	From July 24 to 29, a. m. Without exception in all the observations.		July 24, top-gallant gale; July 25, reefed top-sail breeze; July 26, top-sail breeze; July 27, top-gallant gale; July 28, top-sail breeze; July 29, top-gallant gale.		
		July 30, 9 a. m. Became fit for use again at 9.19, about 30 seconds after the springing of a sleeping mine.	Flood.....	Top-gallant gale.....	July 30, in proper order.	Position of alarms as above.
4	July 21.....				July 30, but more sensible.	
5	July 21.....	July 30, 9 a. m. Became entirely useless at 9.19 by the springing of the sleeping mine.	Flood.....	Top-gallant gale.....	July 30, same useless.	
6	July 19.....				July 31, same.	
7	July 18.....				July 31, in proper order.	
1	Not used.....					
2	August 2.....	August 5, 9.30, 10 a. m. In half an hour's time, twice for a few moments.	Ebb.....	Soft breeze.....	August 15, in good order.	
		August 6, 3 p. m. In order again after having twice interrupted and closed the current for a moment.	Flood.....	Top-gallant gale, showery.		
		August 6, 7 p. m. In order again after having for a moment interrupted and made the current.	Still water.....	do.....		The alarms were placed for betraying a monitor in $\pm$ 7 meters water.
		August 7, 8 a. m. The same.....	Still water.....			
3	August 5, 9.30 a. m..	August 5, 2 p. m. till August 6, 3 p. m. In all the observations.	August 5, 2 p. m., rather strong flood.	Soft breeze.....	August 15, in proper order.	

TABLE E.—Table of the untimely speaking of alarms—Continued.

No. of alarm.	Laid in the water and found in order.	Found speaking untimely.	Current noticed when some alarm spoke untimely.	Condition of the weather when some alarm was found to speak untimely.	When lifted and found in what state.	Remarks.
	1873.	August 7, 8 a. m. In order again after having for a moment interrupted and made the current. August 10, 5 p. m. till August 12, 9 a. m. In all the observations.	Still water.			
4	Not used.		August 10, p. m., still water.	Soft breeze		
5	do					
6	do					
7	August 2	August 11, 4.50 p. m. In order again, after having interrupted and made the current.	Still water.	Top-gallant gale	do	
1	August 22	August 22, 2 p. m. In order again after having for a moment interrupted and made the current. A few minutes after stirring again and further for some few seconds every time during about three-quarters of an hour. Sometimes it was in order from five to ten minutes. Between the last observations, even twenty-five minutes at 3 o'clock, the alarm was seemingly in proper order. August 23, 8 a. m. In order again after having for a moment interrupted and made the current. August 23, 2 p. m. The same	Ebb	Soft breeze	September 2, in proper order; sensibility considerably altered by the springing of the sleeping mine.	
			Flood	Soft breeze		
			Ebb	do		Position of alarms as above.
2	August 22				September 1, in good order.	
3	August 22				do	
4	August 20				September 2, in good order.	
5	August 20				do	
6	August 22				September 1, in good order.	
7	August 20				September 2, in good order.	
1	Not used.					

2	Sept'ber 9, 10.15 a. m.	September 9, 3.30 p. m. The alarm being observed at the turning of the tides, still water, and flood, continued speaking. It was not found in proper order until the next day.	Ebb, still water, flood.	Top-gallant gale	September 22, in proper order.	Position of alarms as above.
3	September 10	September 10, 9 a. m. In proper order after having interrupted the current for 30 ± seconds and closed it again.	Ebb	From September 15 to 16, at night: tempests from west and northwest.	September 20, in proper order.	
4	September 10				do	
5	September 8				September 22, in proper order.	
6	September 8				do	Alarms Nos. 1, 2, and 3 were regulated the least insensible; Nos. 5, 6, and 7 a little more insensible; alarm No. 4 the most insensible.
7	September 8				do	
1	October 3	October 6, 8 a. m. In proper order, after interrupting the current for a few seconds, and closed it again. October 8, 3 p. m. The same. October 11, 8 a. m. The same	Flood	Top-gallant gale	October 14, in good order.	
2	October 4	October 5, 5.30 p. m. In proper order, after interrupting the current for a few seconds and closing it again.	Ebb	Soft breeze Double-reefed top-gallant breeze showing.	October 13, in good order.	
3	October 4	October 6, 8 a. m. Did not get at rest, after having interrupted the current with short and long intervals, and then closed it again; the cable was then detached from the battery; alarm found in order at 5.	Flood when the alarm was found speaking for the first time.	Top-gallant gale	do	
		October 7, 9 a. m., till October 8, 2 p. m. Always in every observation. October 8, 2 p. m. Crossing experiments were made with the Buffet.	Again flood	Top-gallant gale		
		October 9, 8 a. m., till October 10, 1.15 p. m. Always in every observation. (October 10, 1.15 p. m. H. M. Schorpien passed over the mines.)	October 9, 8 a. m. Flood.	Soft breeze		
4	October 2				October 14, in good order.	
5	October 6				October 13, in good order.	
6	October 3				do	
7	October 4				do	

N. B.—As with the exception of the experiments in Helsdeur, the instruments were electrically connected with the alarm-battery as long as they were in order; it may be that an alarm found speaking during still water became useless by ebb or flood.

INDEX.

A.

	Page.
Alliance machine, measurements of	204
Arago disk dynamo	62
Arc lamps, regulators	114
Austrian battery	19

B.

Batteries, list of	13
Beacon tower at Hell Gate	223
Bell-push battery of M. Skrivanow	26
Berjot lamp, Serrin	217
Berjot regulator	125
Bliss and Hill's battery	19
Bonlignine lamp	163
Brush machine	39
Brush regulator	136

C.

Cance's regulator	115
Carbon filament lamps	175
Circuit closer, Mathieson's improved	238
Circuit closer, McEvoy's	243
Commutator at La Héve	205
Commutator, English form of	215
Commutator, Planier	213
Conductors, Edison's	180
Current regulator, Edison's	184

D.

Daniell's battery, Siemens's and Halske's form of	17
Daniell cell modified by M. Planté	26
De Changy's lamp	157
De Meriten's machine	218
De Meriten's machine, measurements of	204
De Mersanne regulator	151
Deprez magneto-electric exploder	110
Derived circuit lamps, regulators	149
Deselle's battery	26
Differential lamps, regulators	125
Disconnecter, Mathieson's	239
Ducrotet lamp	169
Dynamo and magneto electric machines	28

E.

	Page.
Edison dynamo	59
Edison's lamp	157
Edison's system of lamps with carbon filaments:	
Conductors	180
Current regulator	184
Junction boxes	181
Manufacture of the lamps	177
Meters for electricity	185
Switches	182
The lamps	175
Electric light, application of, to lighting coasts of France	197
Electric light for military purposes, list of apparatus	71
Exploders, list of	107

F.

Fontaine's lamp	163
France, application of electric light to lighting coasts of	197
French lights, characteristics with oil lamps	203
characteristics with electric lights	204

G.

Gaiffe's battery	20
Gramme continuous-current machine	33
Gramme electric-motor, small size	39
Gramme machine for transport of power	36
Gramme machine, measurements of	35
Gramme machine, small, for hand power	75
Gramme regulator	149
Griscom bichromate battery	15
Gulcher dynamo	57
Gulcher regulator	142

H.

Hedge's regulator, differential lamps	134
Hedge's regulator, monophotes	118
Hefner-Alteneck continuous-current dynamo	47
Hell Gate, beacon tower at	223
Hopkinson Muirhead dynamo	51
Howell's manganese battery	23

I.

Imperfect contact lamps	164
Inclosed carbon lamps	159
Incandescent lamps	155

J.

Jablochkoff alternating current dynamo	68
Jaspar regulator	120
Joel lamp	175
Junction boxes, Edison's	181
Junction-box, McEvoy's	244
Junction-box, exhibit of Silvertown Company	241
Jurgensen dynamo	65

K.

Kaiser's torpedo alarm	Page 247
Key-board, McEvoy's	243
King's lamp	160
Kohn's lamp	161

L.

La Hève:

Commutator at	205
Lantern for electric light at	206
Light-house at	197
Rails for electric lights at	207
Lamps, incandescent	155
Lamps with carbon filaments:	
Edison's system	175
The Lane-Fox lamp	194
The Maxim lamp	189
The Swan lamp	192
Lamps with imperfect contact:	
Ducretet's	169
Joel's	175
Reynier's	164
Varley's	164
Werdermann's	163
Werdermann's, improved by Napoli	171
Lamps with inclosed carbons:	
Boulignine	163
Fontaine's	163
King's	160
Kohn's	161
Lamps with platinum spirals:	
De Changy's	157
Edison's	157
Moleyns'	156
Petrie's	156
Lane-Fox regulator	195
Lantern for electric light at La Hève	206
Fleclanché battery	21
Light-house with vertical rays	222
London post-office standard battery	25

M.

Machines, dynamo and magneto electric	28
Maiche's battery	22
Mangin projector, the	81
Mangin projector, mounted on a cart	83
Marie-Davy's battery, Siemens and Halskes' form of	18
Mathieson's disconnecter	239
Mathieson's improved circuit-closer	238
Maxim dynamo	56
Maxim lamp, the	189
Maxim regulator, the	190
McEvoy's single main torpedo system	242
circuit-closer	243
junction-box	243
key-board	243

	Page.
Measurements of Alliance machine.....	204
De Meriten's machine.....	204
Gramme machine.....	204
Meters for electricity, Edison's.....	184
Military purposes, electric light for, list of apparatus.....	71
Military telegraphs, list of apparatus.....	228
Moleyns' lamp.....	156
Monophotes, arc lamp regulators.....	115
Moser's battery.....	20

P.

Pacinotti ring.....	28
Palmyre, lantern for electric light.....	211
Partz's bichromate battery.....	24
Petrie's lamp.....	156
Piatti battery.....	24
Pilsen regulator.....	129
Planier :	
Commutator.....	213
Lantern for electric lights.....	209
Light-house at.....	208
Optical apparatus.....	209
Plan of building containing quarters.....	210
Planté modification of Daniell cell.....	26
Platinum spiral lamps.....	155
Projectors:	
The Mangin, mounted on a cart.....	83
The Mangin.....	81
Santter and Lemonnier's, for ships' boats.....	79
Santter and Lemonnier's lenticular, large size.....	77
Santter and Lemonnier's, mounted on a cart.....	78

R.

Rails for electric lights at La Hève.....	207
Rays, vertical, light-house with.....	222
Refining metals, Siemens dynamo for.....	46
Regulators, list of:	
Berjot differential lamps.....	125
Brush differential lamps.....	136
Cance's monophotes.....	115
De Mersaune, with derived circuit.....	151
Edison's current.....	184
Gulcher differential lamps.....	142
Hedges differential lamps.....	134
Hedges monophotes.....	118
Jaspar monophotes.....	120
Lane-Fox current.....	195
Maxim.....	190
Pilsen differential lamps.....	129
Siemens differential lamps.....	147
The Gramme, with derived circuit.....	149
Weston differential lamps.....	127
Reynier lamp.....	164

S.

	Page.
Sautter and Lemonnier's lenticular projector, large size	77
Sautter and Lemonnier's projector, mounted on a cart	78
Sautter and Lemonnier's projectors for ships' boats	79
Schuckert dynamo	59
Serrin-Berjot lamp	217
Seven shutter signaling and firing instrument	232
Siemens alphabetical telegraph	228
Siemens and Halske's constant battery	16
Siemens and Halske's form of Daniell's battery	17
Siemens and Halske's form of Marie-Davy's battery	18
Siemens dynamo	43
Siemens dynamo-electric mine-exploder for quantity	109
Siemens dynamo-electric mine-exploder for tension	107
Siemens dynamo for refining metals	46
Siemens magnetic electro dial instrument	230
Siemens magneto-electric mine-exploder	107
Siemens regulator	147
Skrivanow's bell-push battery	26
Standard battery, London post-office	25
Swan Lamp, the	192
Switches, Edison's	182

T.

Telescopic firing-arcs	233
Torpedo alarm, Kaiser's	247
Torpedo apparatus, list of	232
Torpedo fuse	240
Torpedo system, McEvoy's single main	242
Tower for Hell Gate beacon	223
Trouvé bichromate battery	13
Trouvé dry battery	15
Trouvé sealed battery	14

V.

Varley lamp	164
Vertical rays, light-house with	222

W.

Werdermann lamp	168
Werdermann lamp, improved by Napoli	171
Weston dynamo	54
Weston regulator	127

C

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